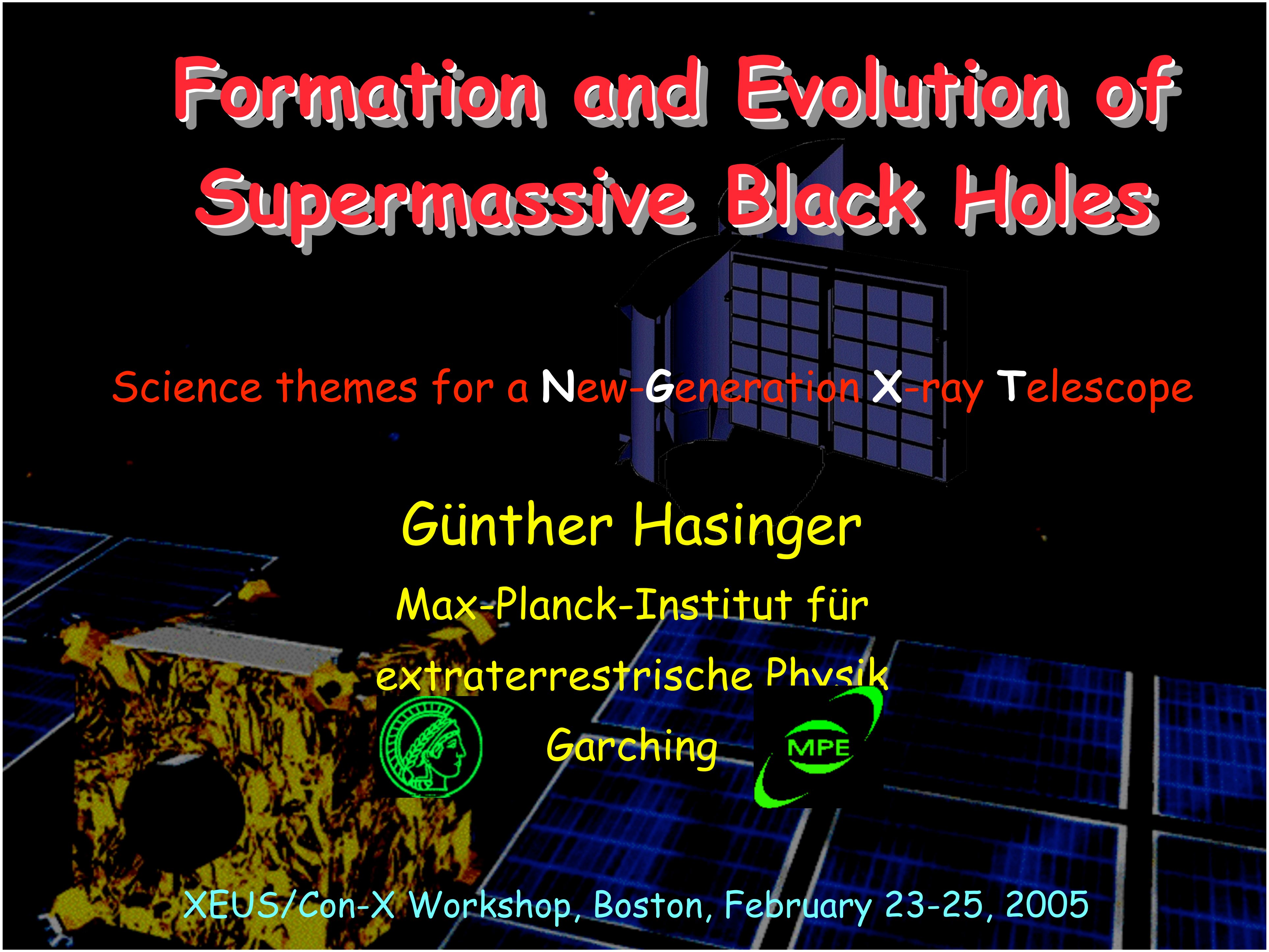
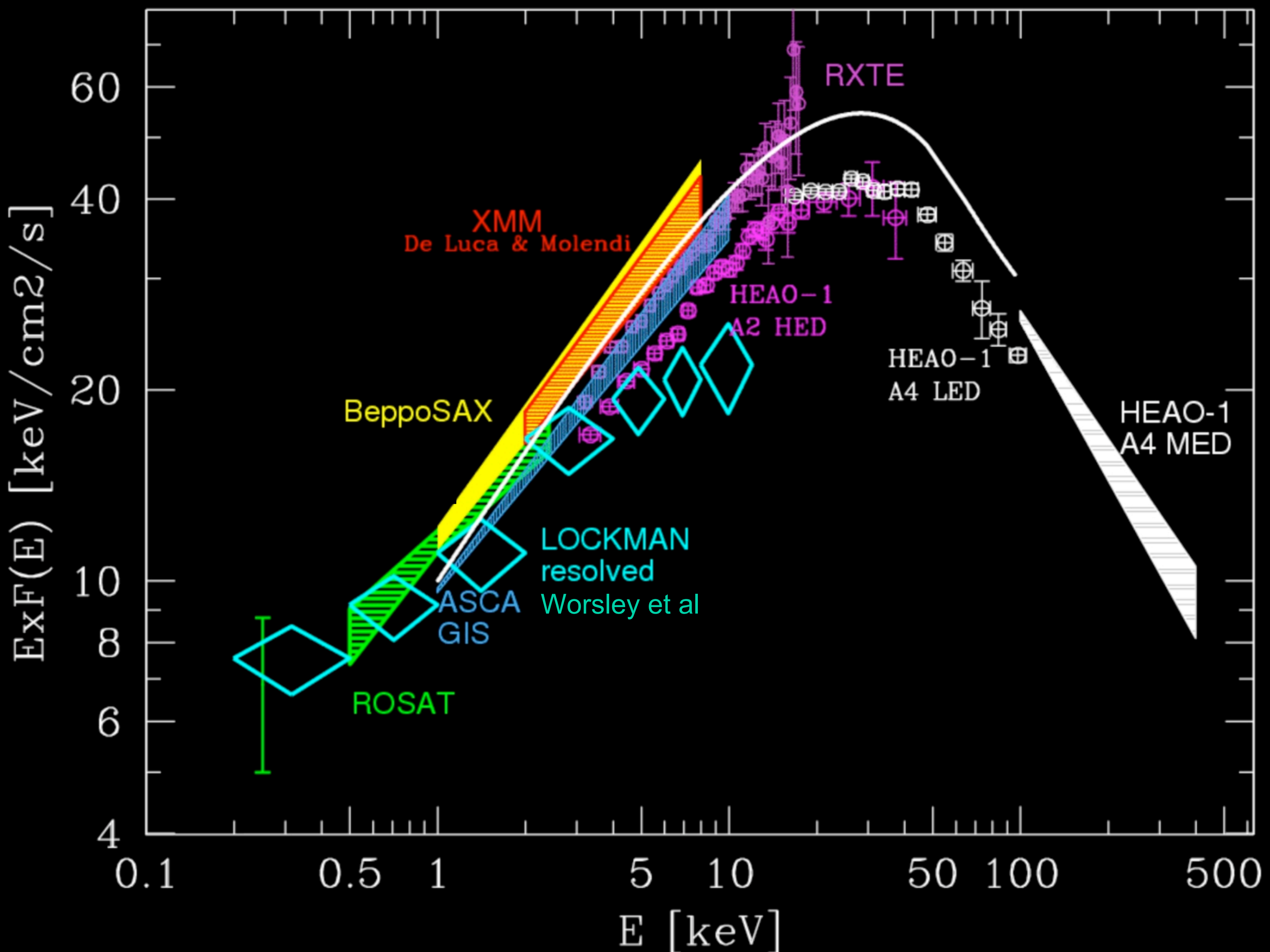
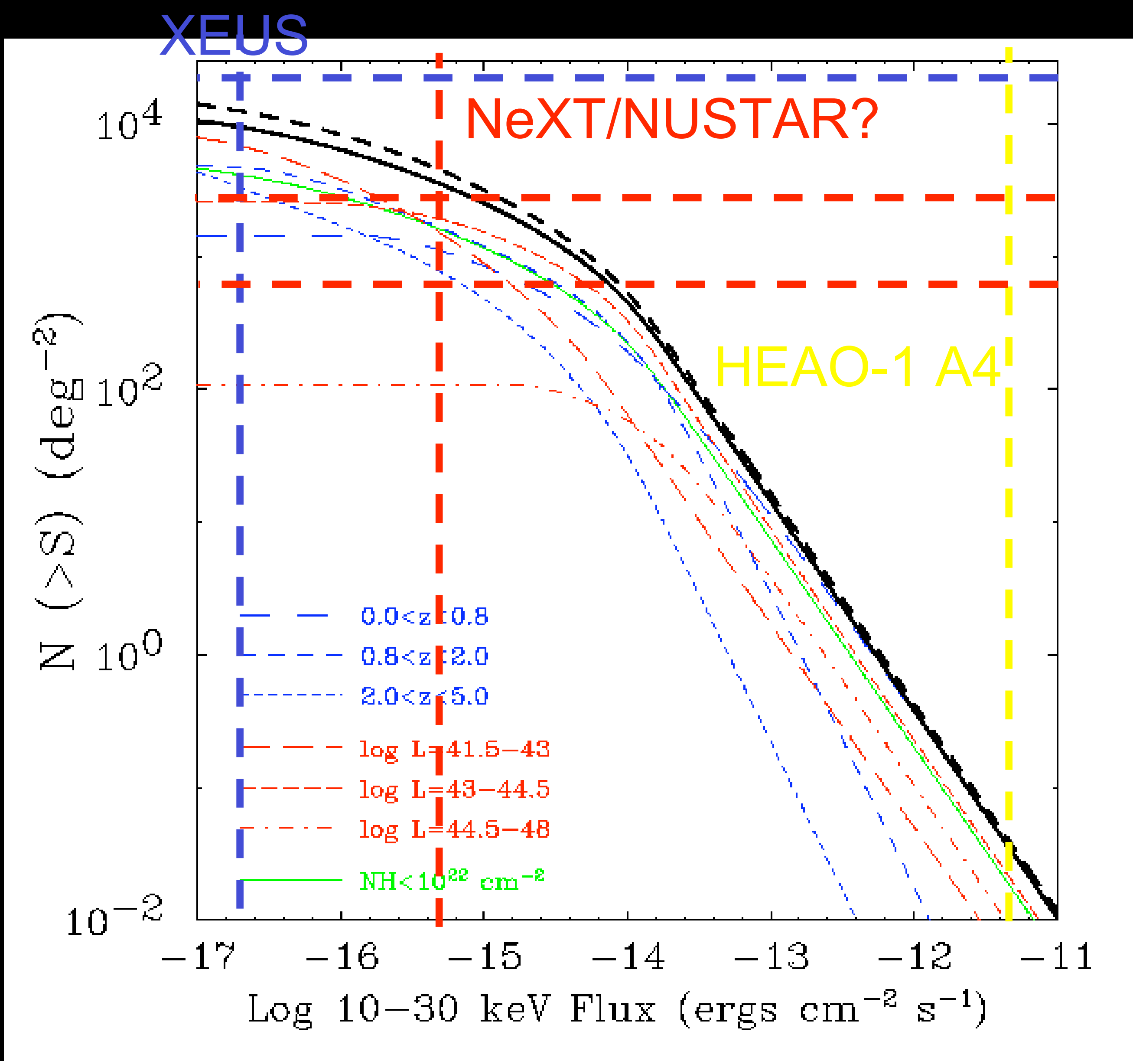

Formation and Evolution of
Supermassive Black Holes
Science themes for a New-Generation X-ray Telescope
Günther Hasinger
Max-Planck-Institut für
extraterrestrische Physik
Garching
MPE
XEUS/Con-X Workshop, Boston, February 23-25, 2005

1. Evolving Violent Universe

X-ray background and resolved fraction



10-30 keV Number Counts



Confusion Limit

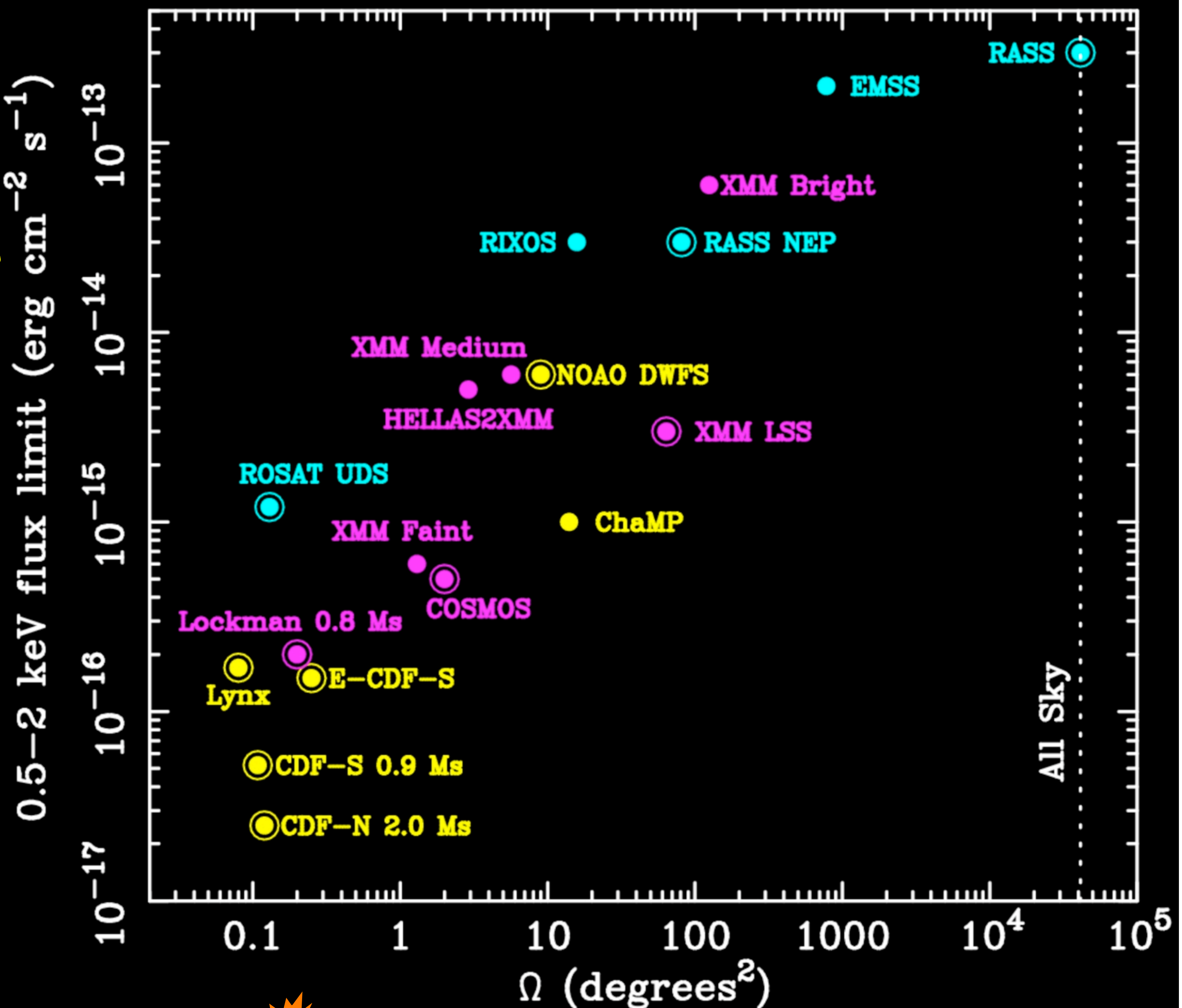
5" HEW

15" HEW

30" HEW

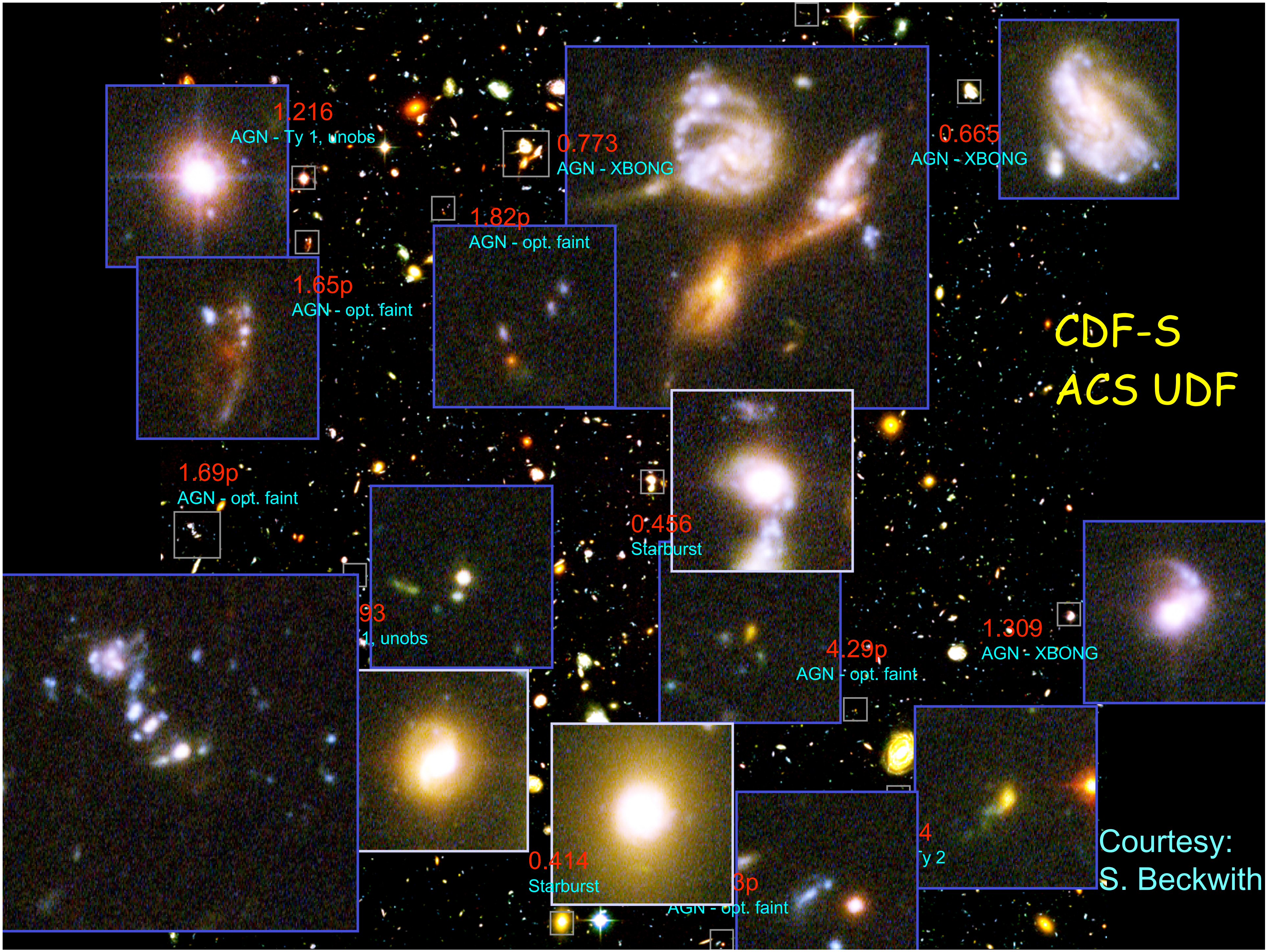
Ueda et al., 2004, ApJ

Large X-ray surveys



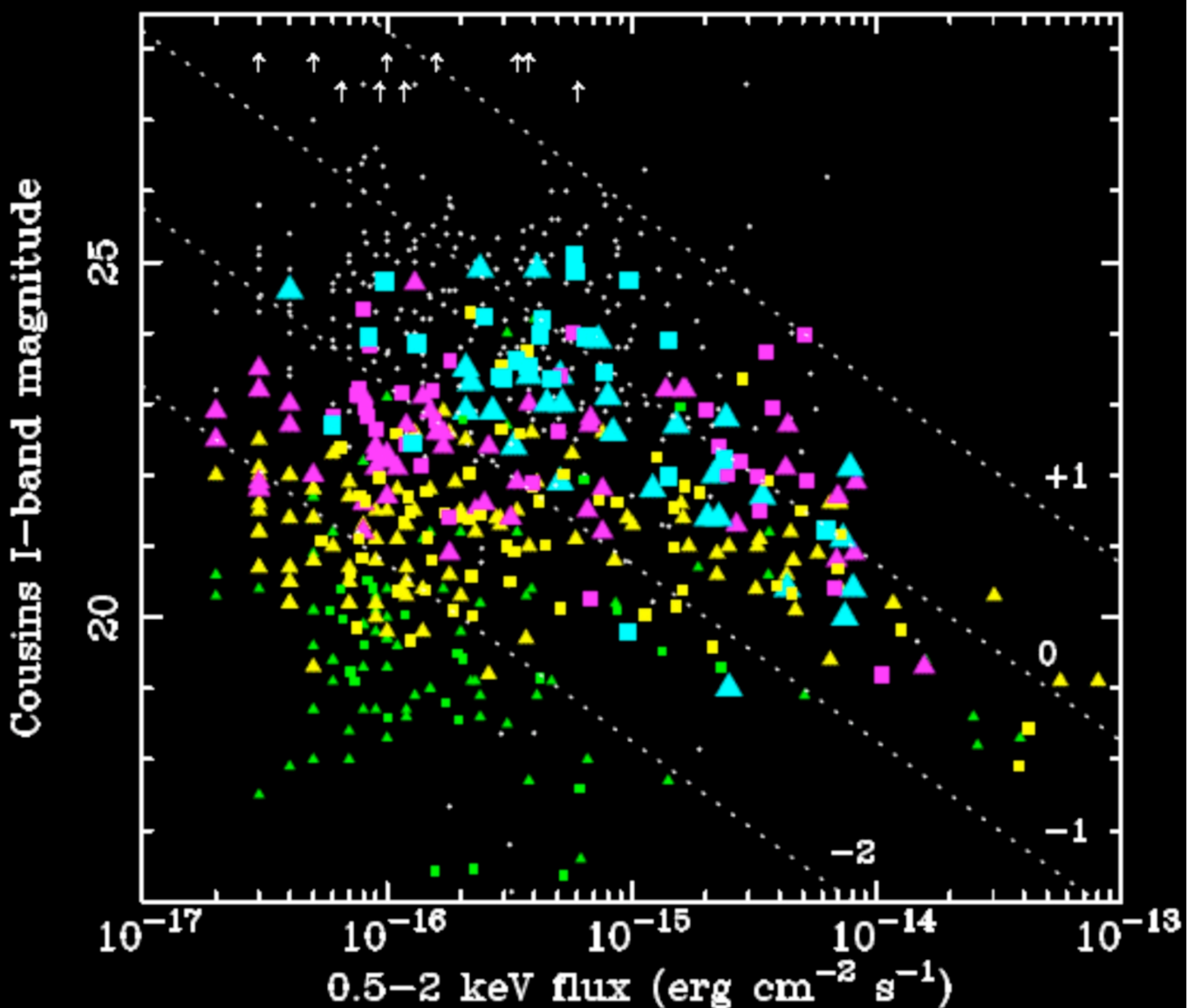
XEUS Deep Surveys
(3 fields 1 Msec each)

N. Brandt & G.H.
2005, ARA&A, in press


1.216
AGN - Ty 1, unobs
0.773
AGN - XBONG
0.665
AGN - XBONG
1.82p
AGN - opt. faint
1.65p
AGN - opt. faint
CDF-S
ACS UDF
1.69p
AGN - opt. faint
0.456
Starburst
93
1, unobs
1.309
AGN - XBONG
4.29p
AGN - opt. faint
4
Ty 2
0.414
Starburst
3p
AGN - opt. faint
Courtesy:
S. Beckwith

Optical Identifications

- Require largest telescopes in the world (Keck, VLT, Subaru)
- Require 4-5 hr integration times
- 30% are too faint for spectroscopy
- photo-zs are possible with exquisite opt/NIR



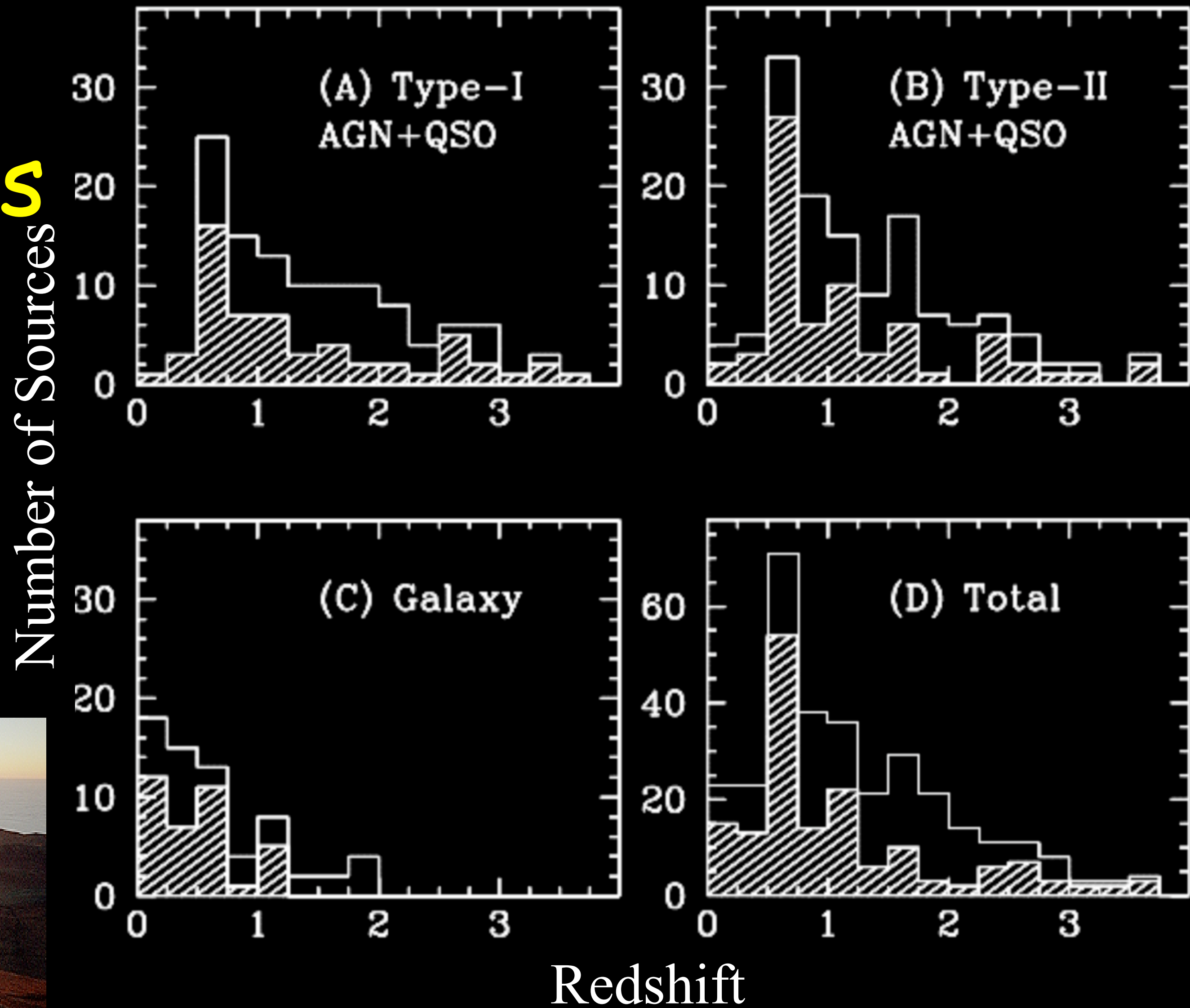
N. Brandt & G.H. 2005, ARA&A, astro-ph/0501058

CDFS Optical IDs

Szokoly et al., 2004
(spectro-z)

Wolf et al., 2004
(Combo-17)

Zheng et al., 2004
Mainieri et al., 2004

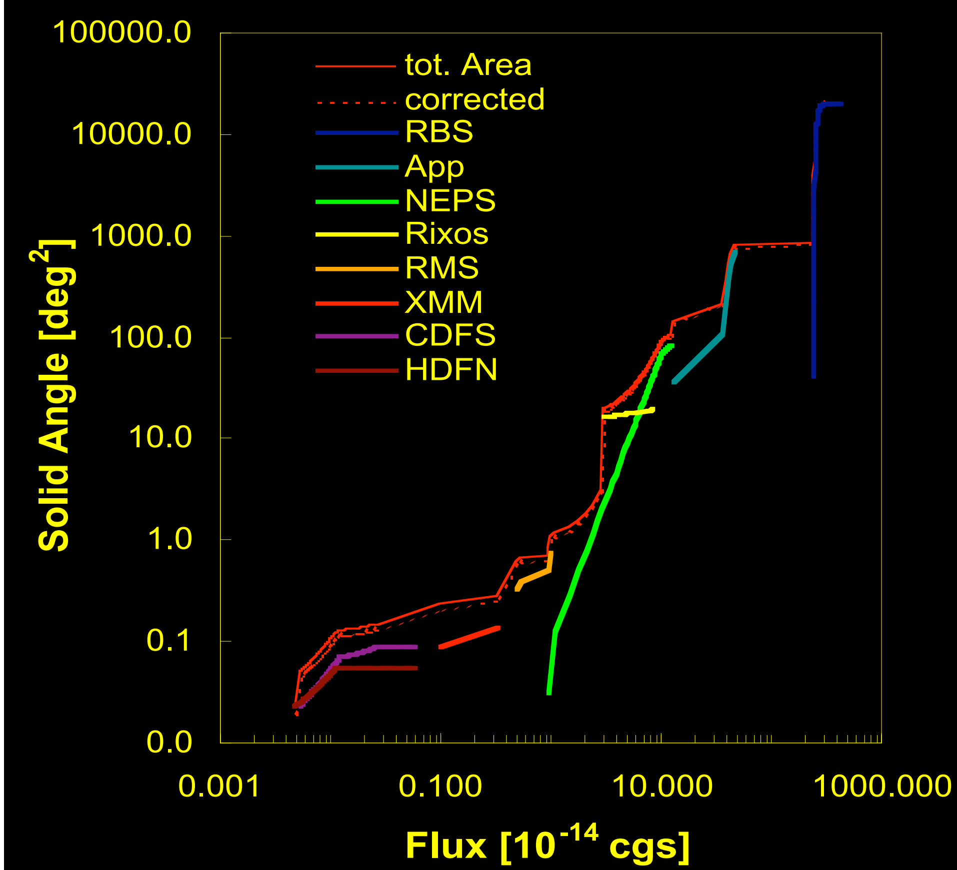


> 95% have spectro- or photo-z thanks to VLT, GOODS, GEMS, ACF UDS etc.

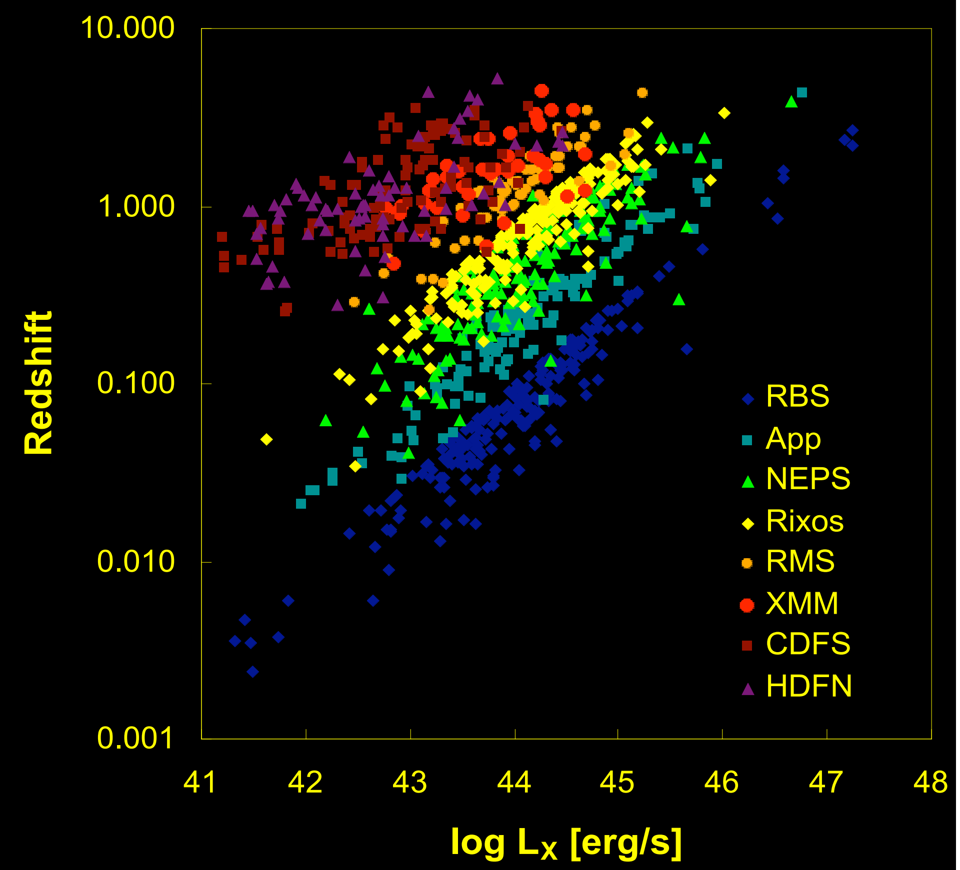
Photo-z at higher z, but all peak at z~0.7

Multi-Cone Surveys

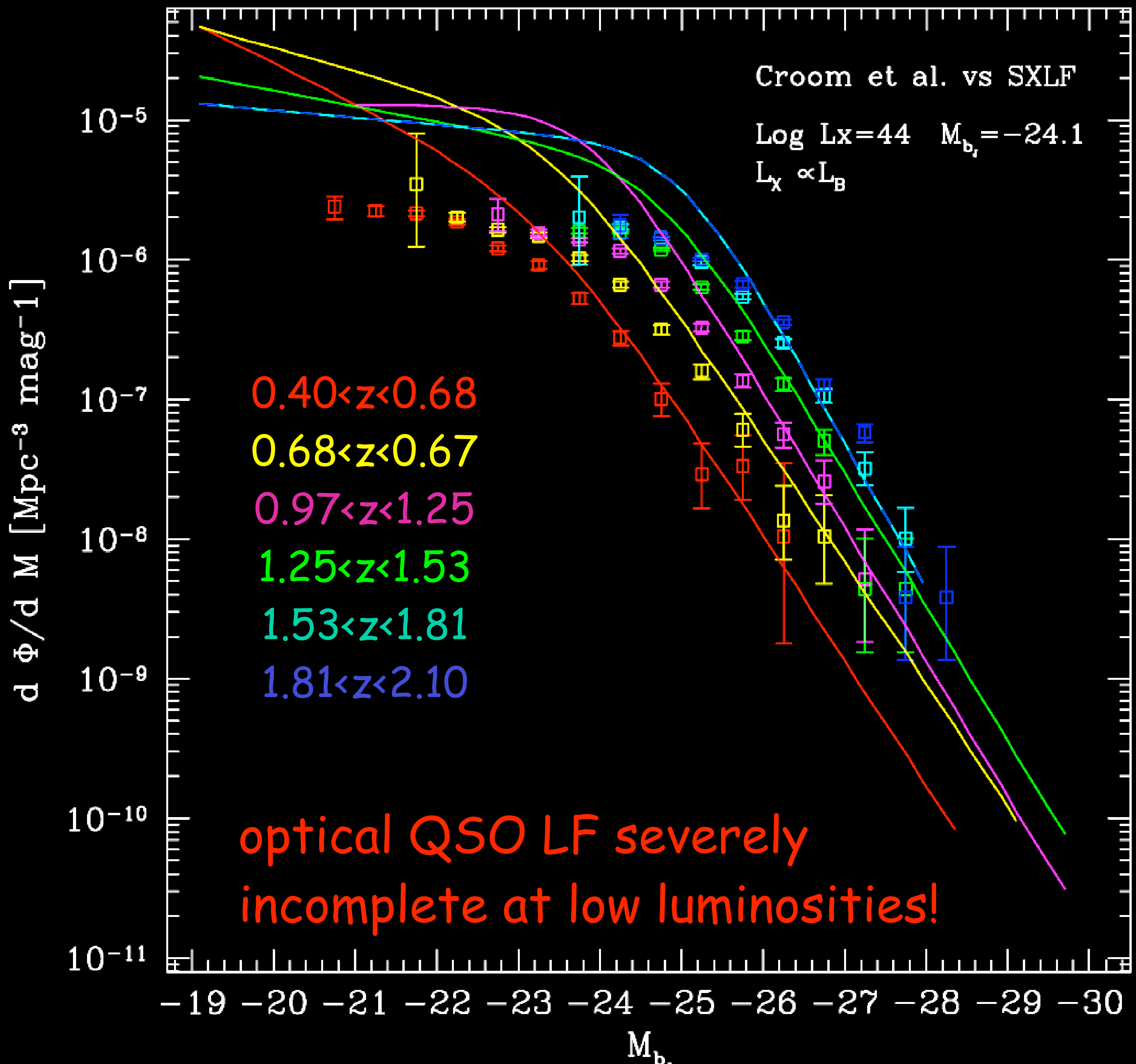
Survey Area



Hubble Diagram

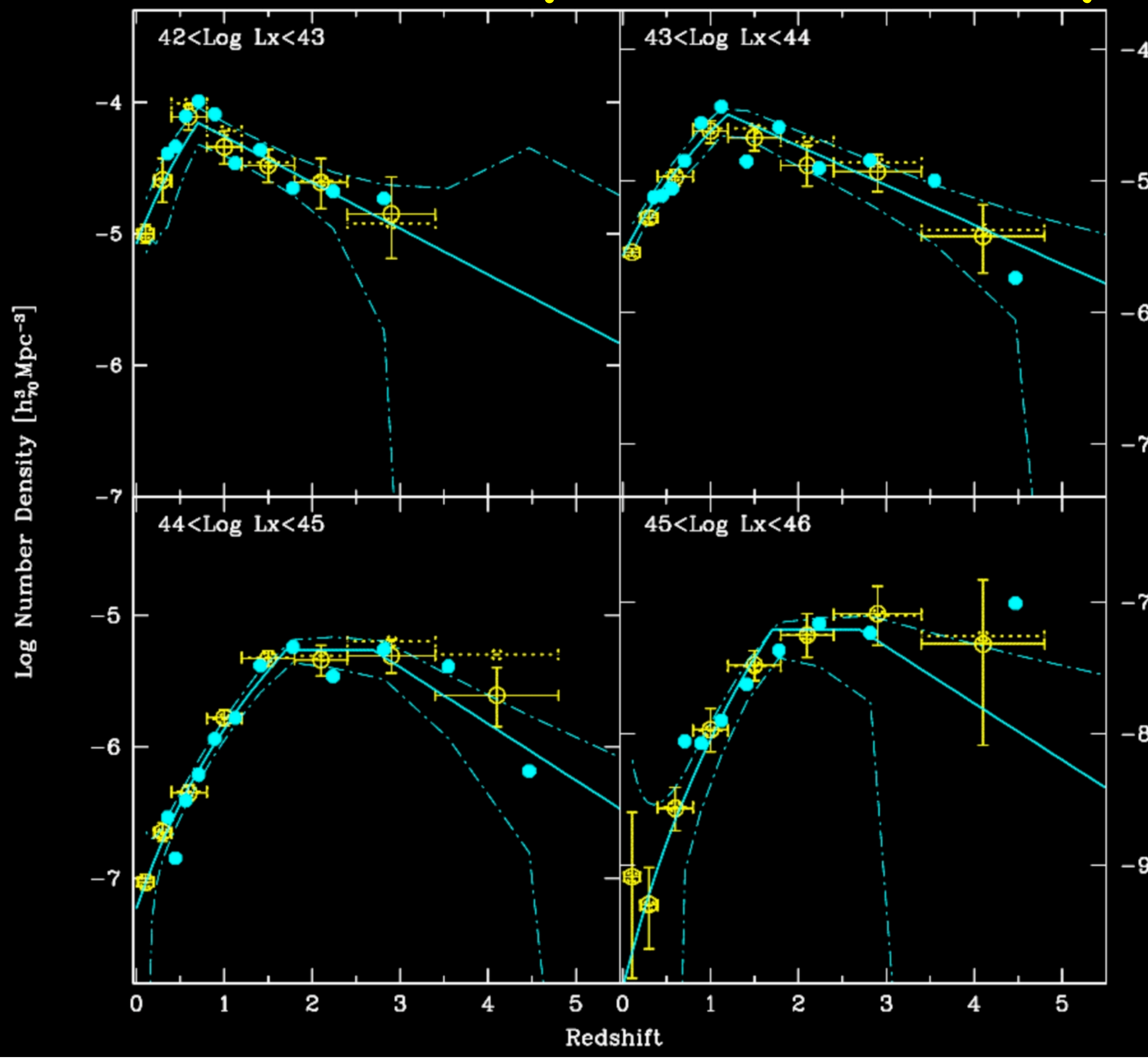


X-ray vs. optical LF



Miyaji, 2005, priv. comm

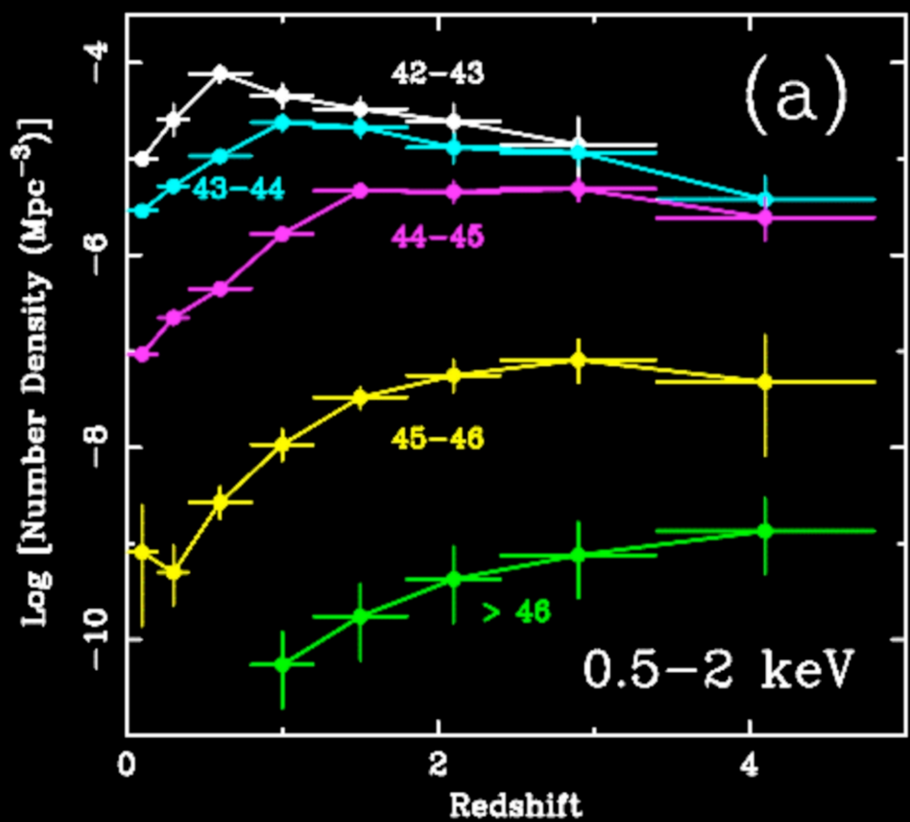
AGN Space Density $\phi(z)$

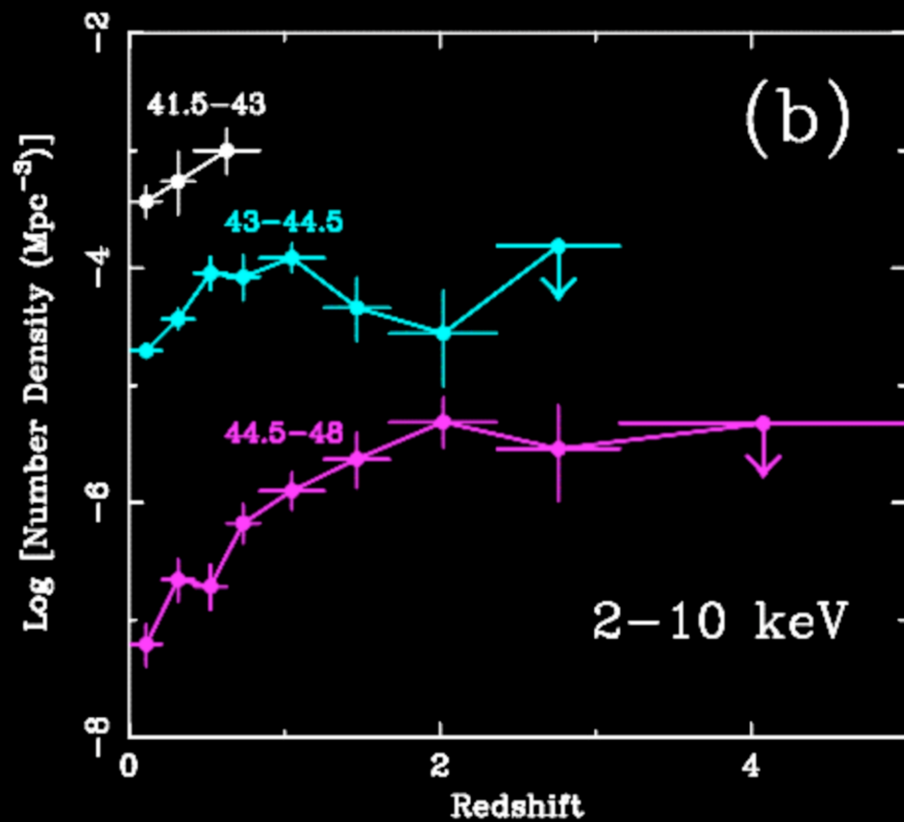


Hasinger, Miyaji & Schmidt, 2004, A&A submitted

M. Schmidt method
T. Miyaji treatment
(dotted: upper limit)

Densities in soft and hard band



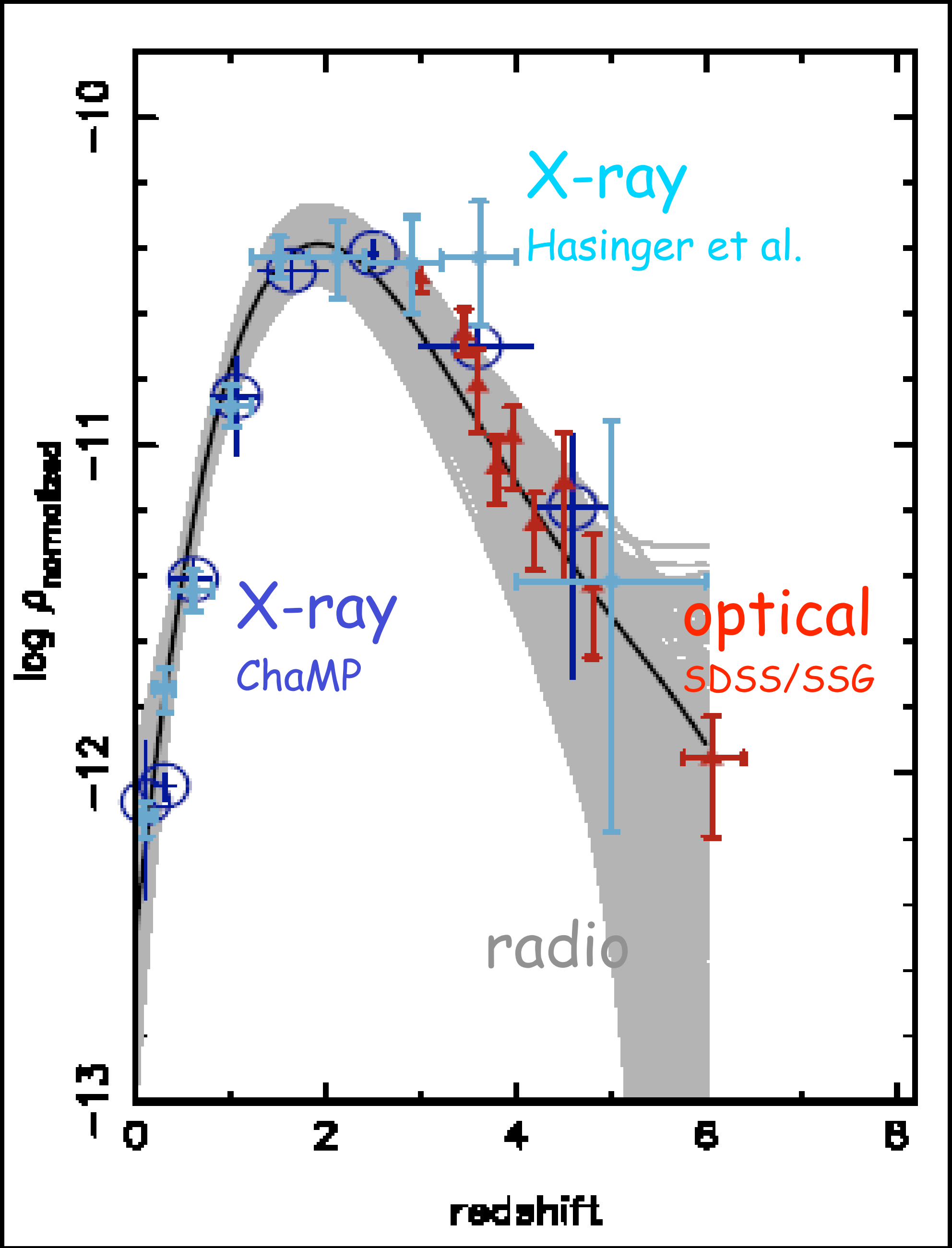


Hasinger, Miyaji & Schmidt, 2005
based on ~1000 AGN-1

Ueda et al., 2003,
based on ~250 AGN

Very similar behaviour in hard and soft band.
Soft samples go deeper and are more complete.

Multiwavelength comparison



Wall et al., 2005 (astro-ph/0408122)

Good agreement for high-luminosity QSO

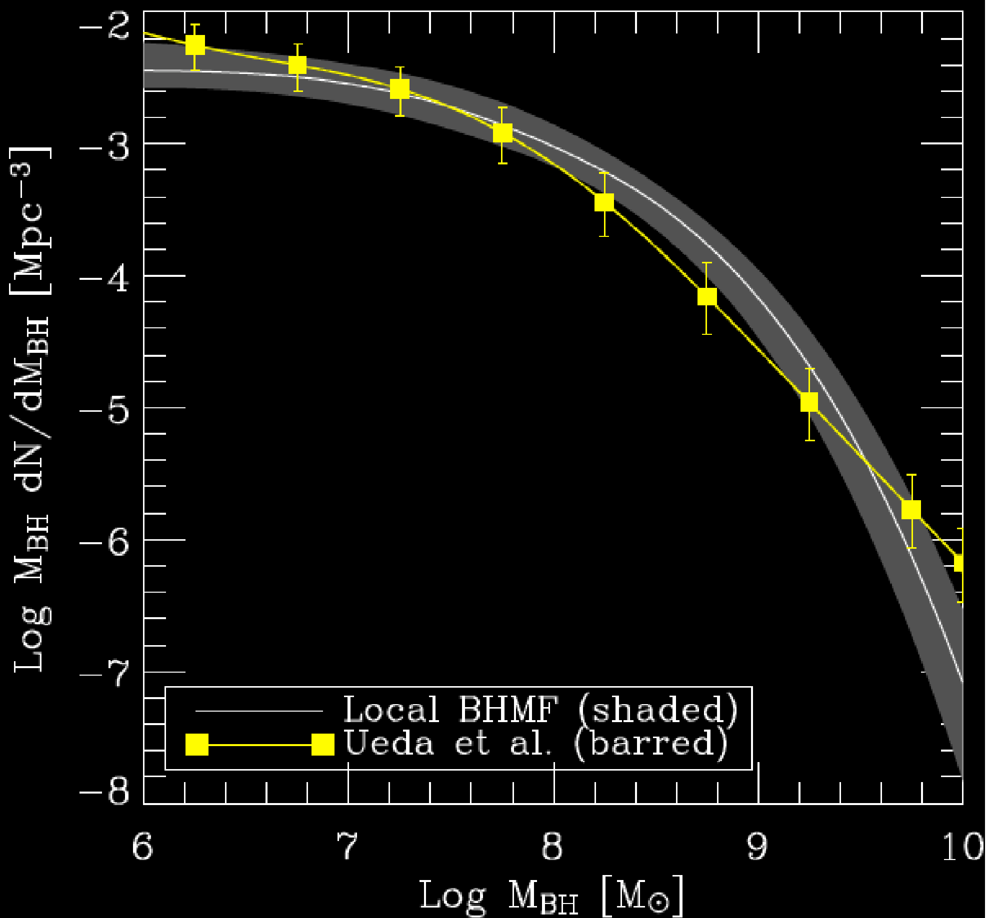
Very large solid angle deep surveys are required to discover z>5 QSOs

<u>Ongoing/proposed:</u>
E-CDFS (1/4 deg^2)
COSMOS (2 deg^2)
ChaMP (10 deg^2)

Local BH mass vs. accreted BH mass function

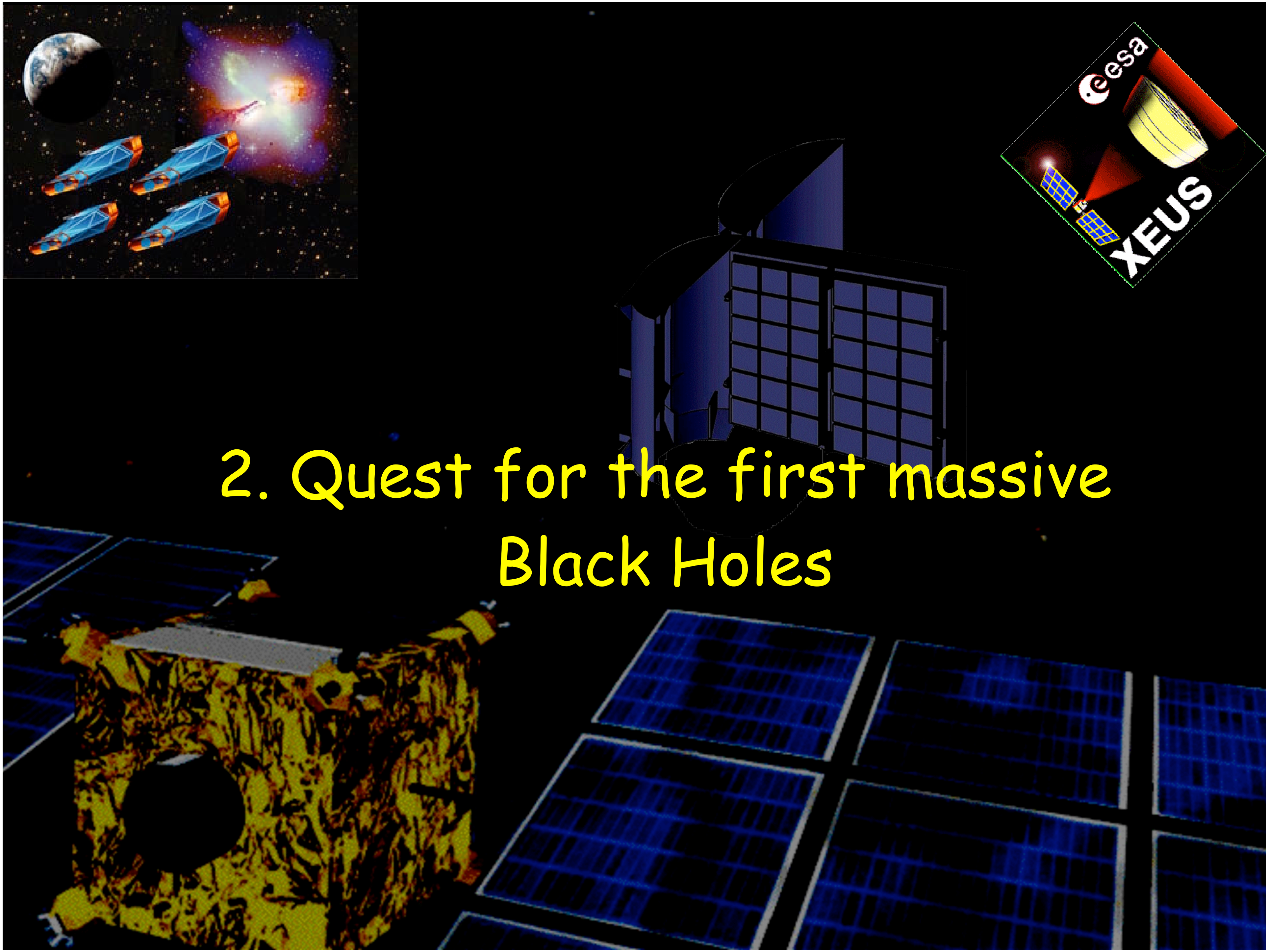
- Accreted Black Hole mass function derived from X-ray background can be compared with the mass function of dormant relic black holes in local galaxies (Soltan 1982).

- These two estimates can be reconciled, if an energy conversion efficiency of _=0.1 is assumed.



Marconi et al., 2004, MNRAS

- Such high efficiency



2. Quest for the first massive Black Holes

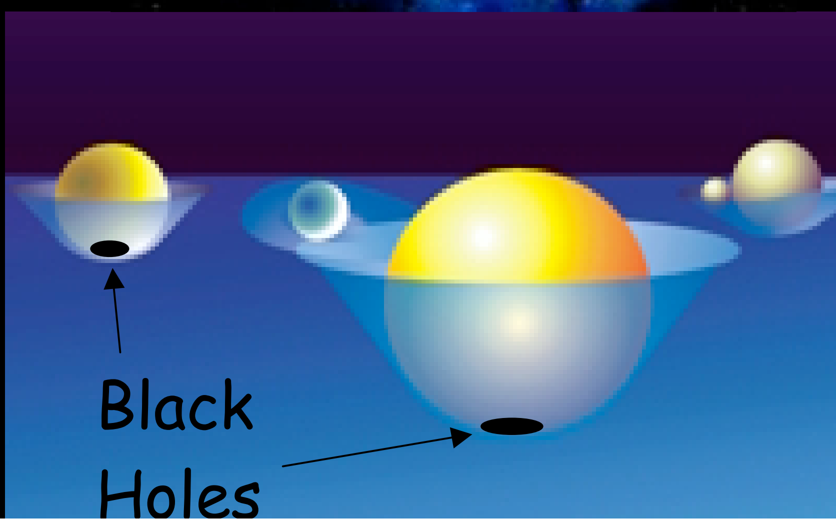
The first Black Hole

Before the first star can form, the universe has to cool down to ~100K to allow molecular hydrogen cooling.

The first star is expected to be massive (~300 $M_\odot$), shines for ~1 Million years, sterilizes its cosmic environment, explodes in a GRB hypernova, pollutes its environment with heavy elements and leaves a seed Black Hole.

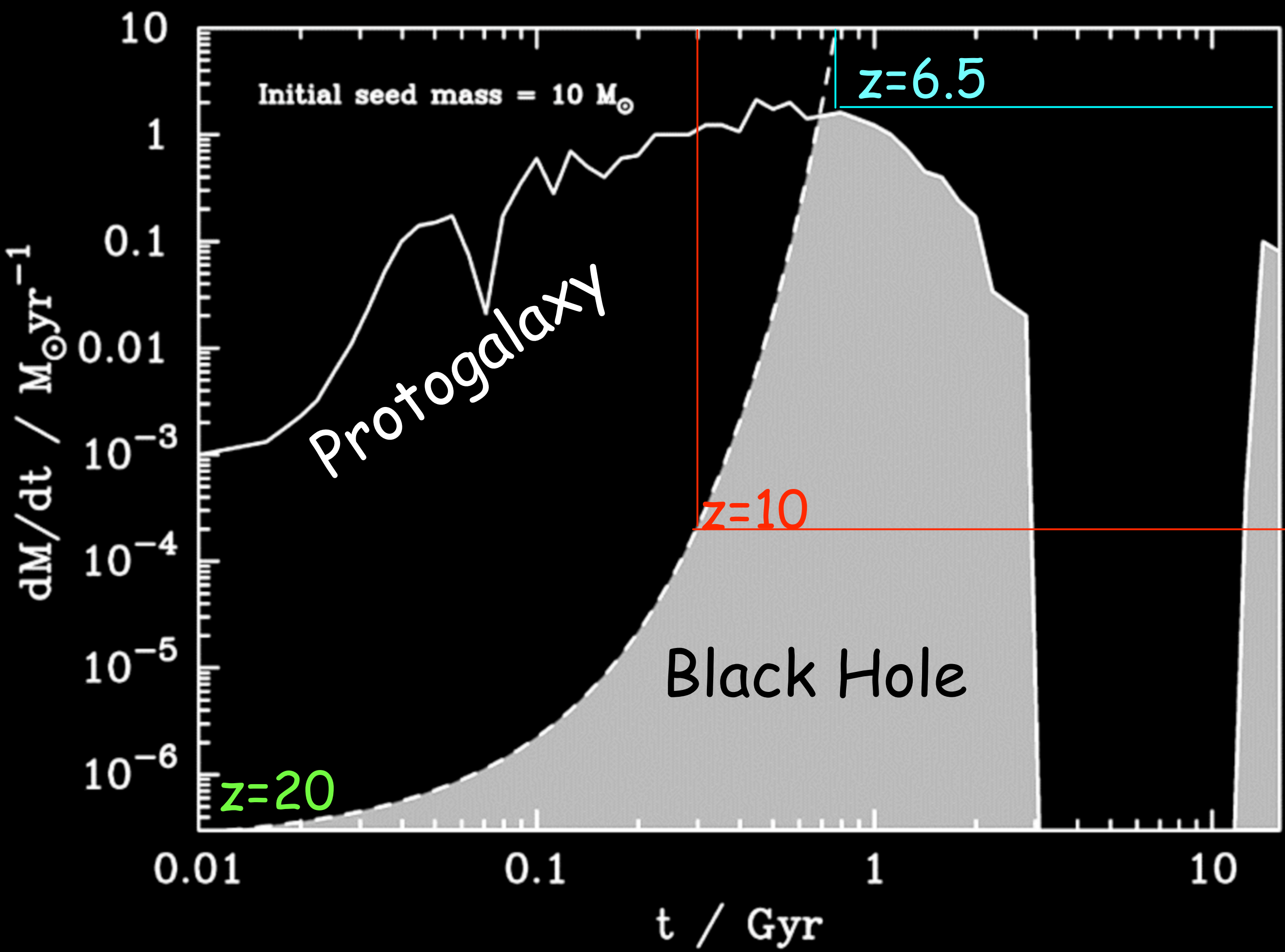
While the galaxy forms, the BH continues to grow exponentially, quickly producing a powerful quasar, if enough fuel can be provided.

Sensitive X-ray observations can study the first GRB explosions and can detect



QSO exponential feeding

Archibald et al. 2001



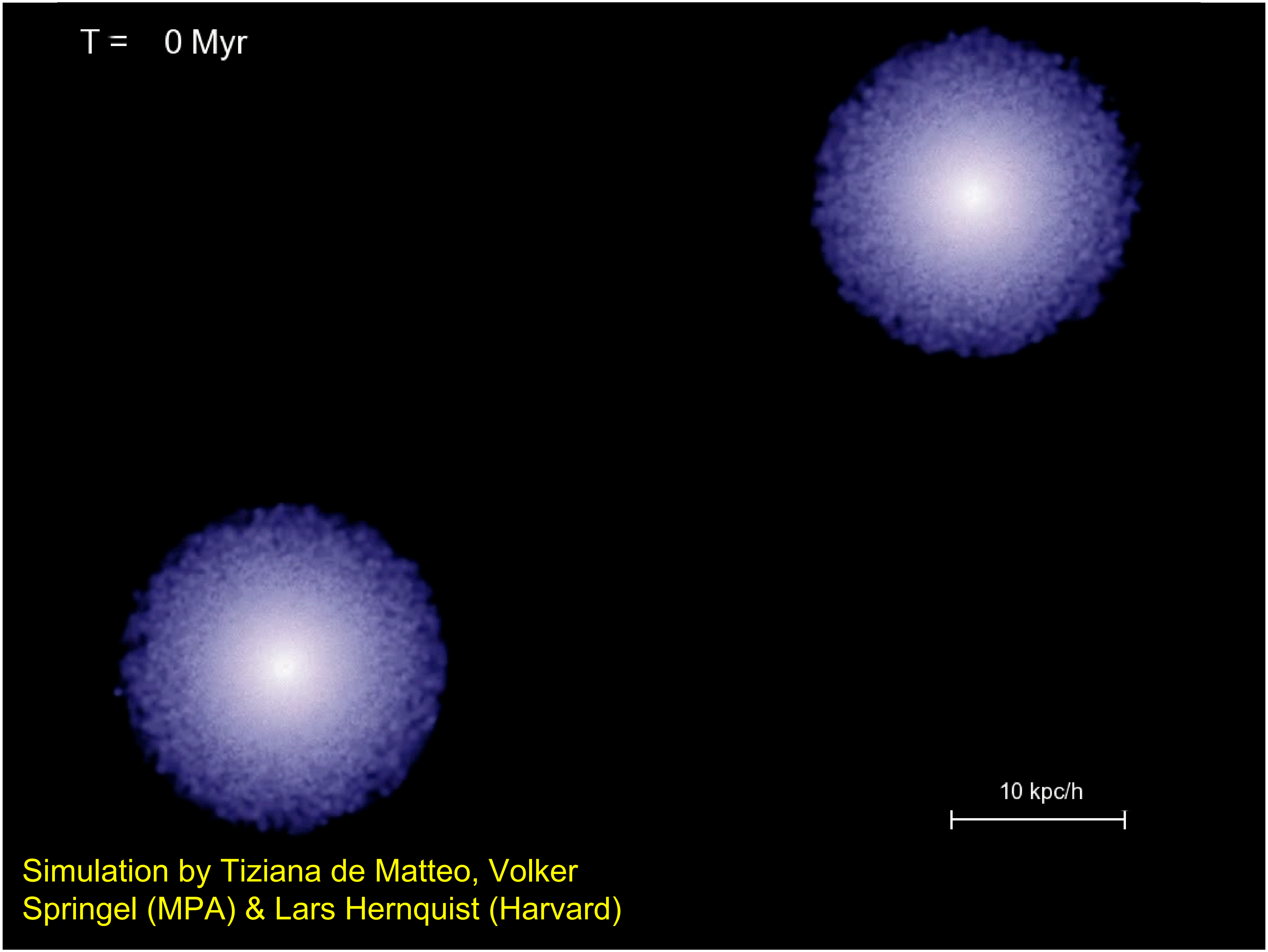
10^8 $M_\odot$
(known QSOs)

10^4 $M_\odot$
Mini-QSOs

10 $M_\odot$
Gamma Burst

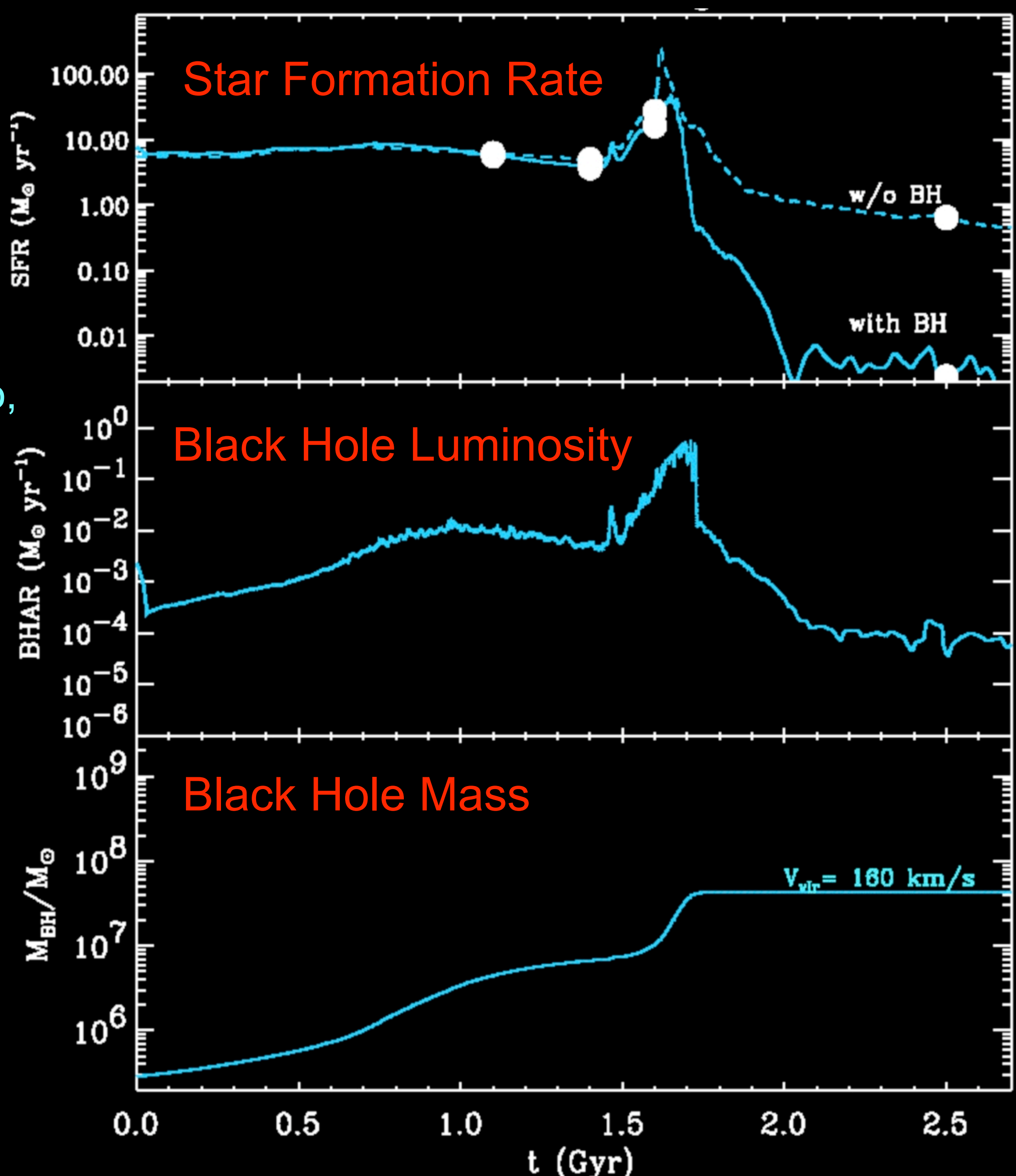
Need New Generation X-ray Telescope to detect and study BH in conjunction with forming galaxy (S_{min} ~ 10^{-18} erg cm^{-2} s^{-1}).

10^4 $M_\odot$ @ redshift 10 detectable.


T = 0 Myr
10 kpc/h
Simulation by Tiziana de Matteo, Volker
Springel (MPA) & Lars Hernquist (Harvard)

Co-evolution of Galaxy and BH

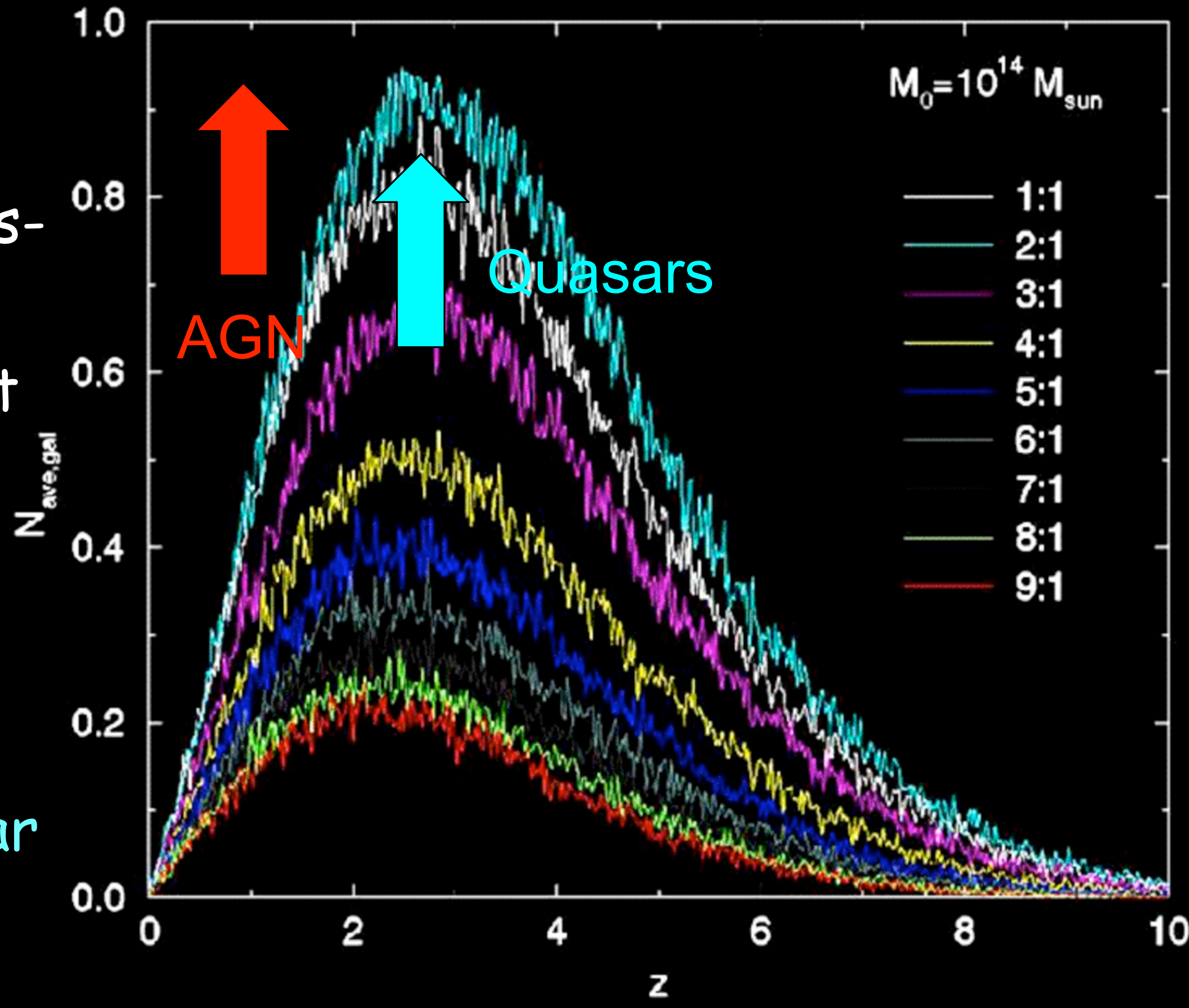
Simulation by Tiziana de Matteo, Volker Springel (MPA) & Lars Hernquist (Harvard)



Expect binary active BH in many pre-QSO AGN

Merger-Rate vs. Redshift

Merger rates derived using Press-Schechter formalism (Burkert et al., 2004)

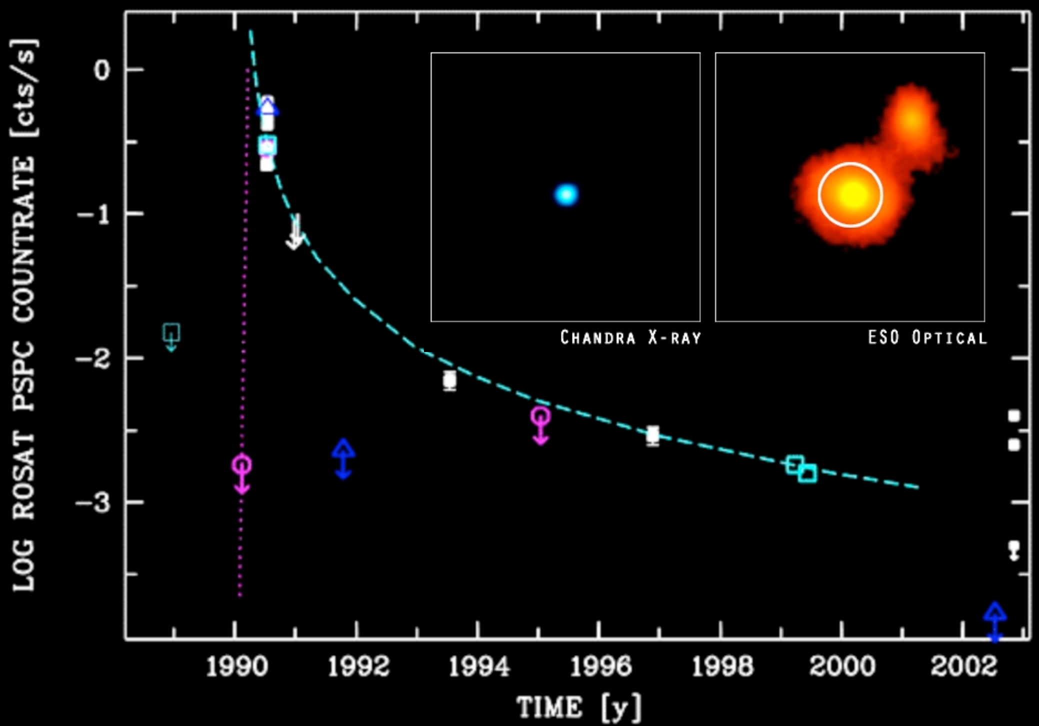


Both major and minor Mergers peak at the Quasar epoch!

=> Need an additional ingredient for low-z Seyfert peak!

Tidal Capture and disruption events

A single star is captured and tidally disrupted by a black hole. After an initial flash of X-rays, there is a steady decline over a timescale of ~10 yr.



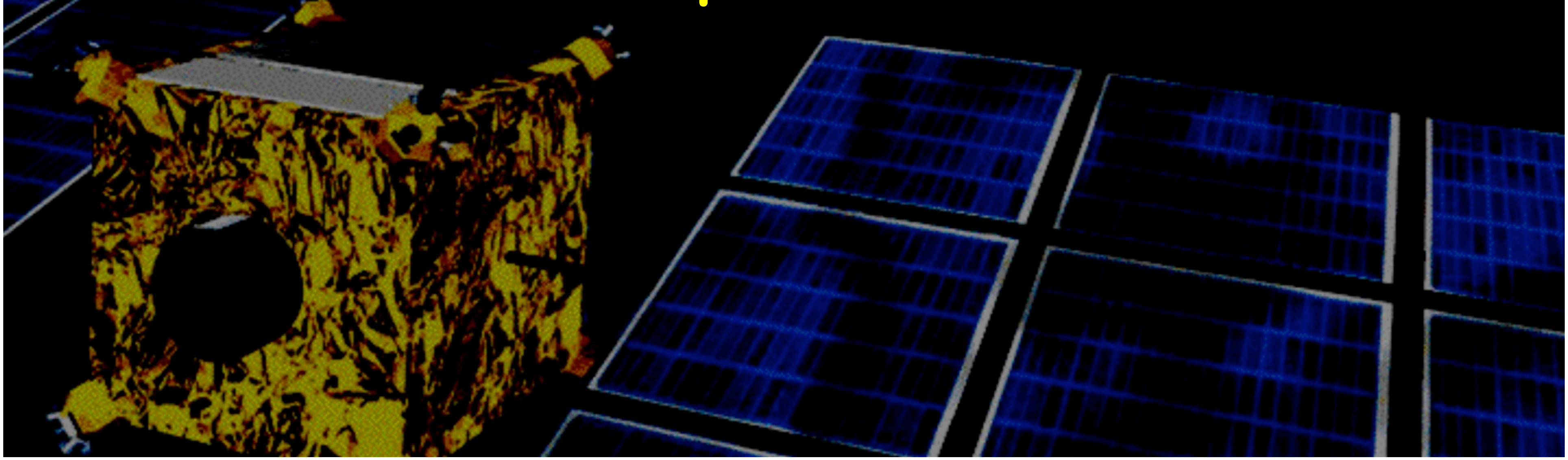
Light curves of 4 tidal capture events discovered by ROSAT.

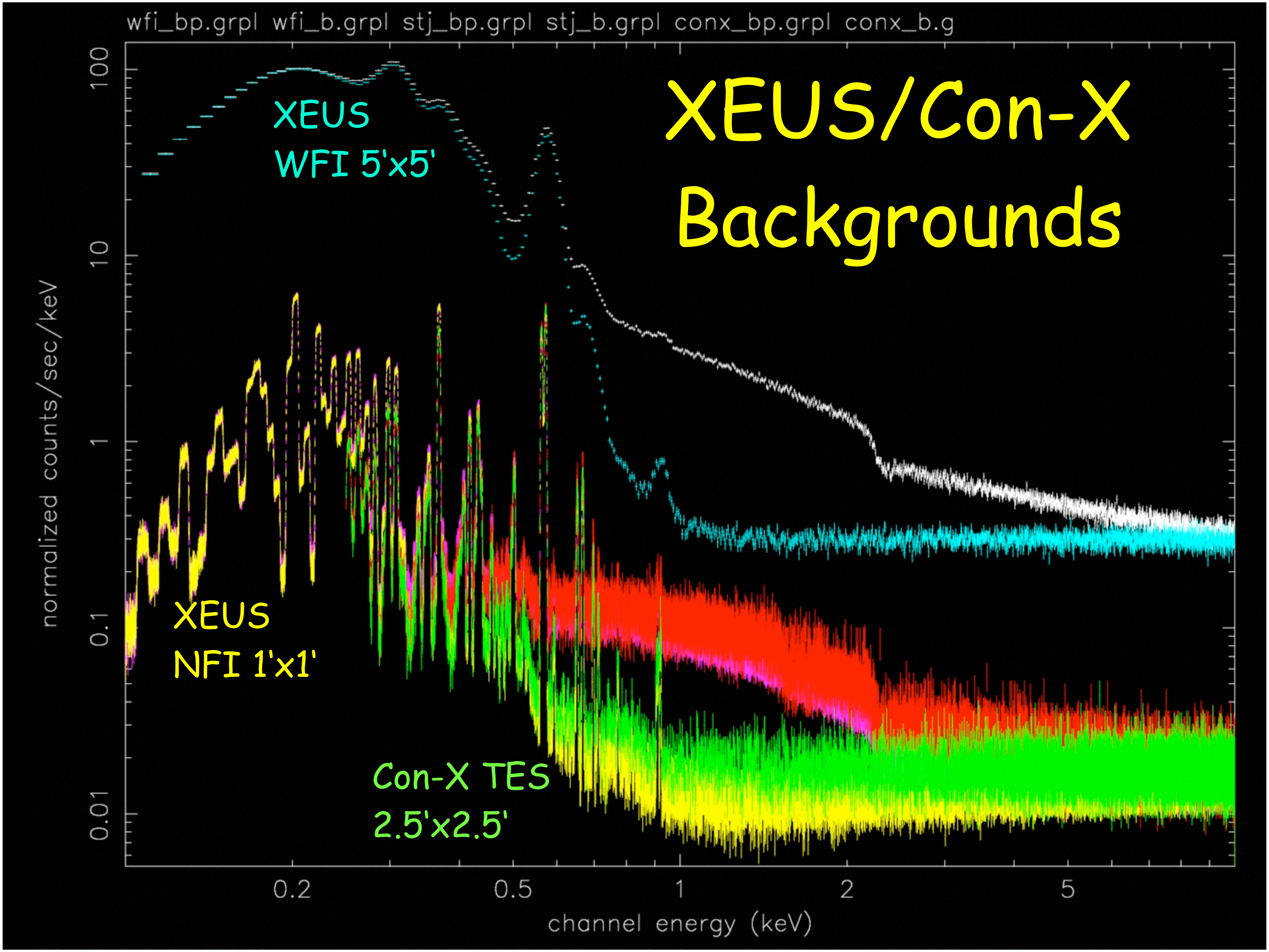
RX J1242-1119 afterglow has been detected and studied by Chandra and XMM-Newton ~10 yrs after the outburst.

Rees 1988

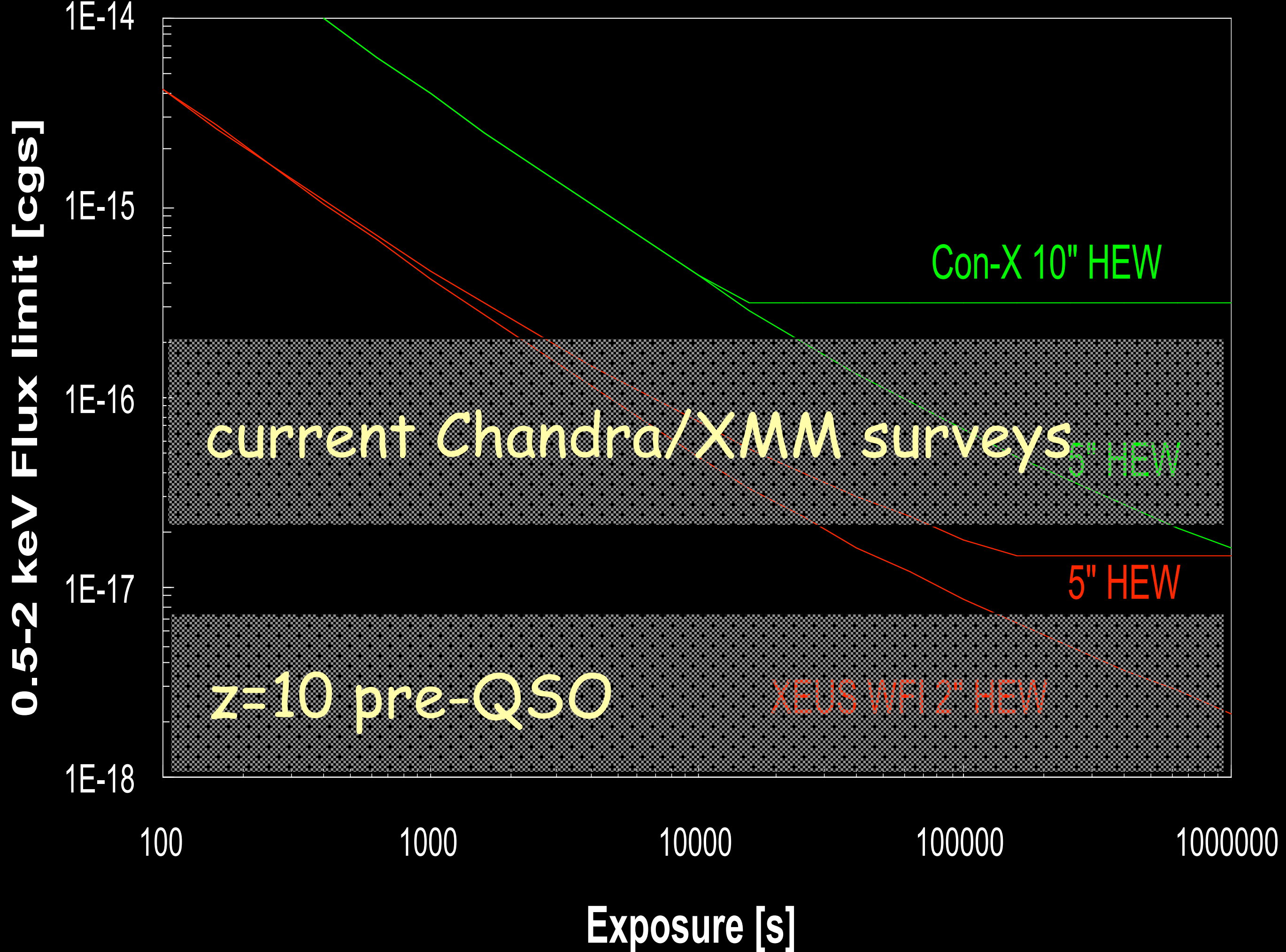
Komossa et al., 2004

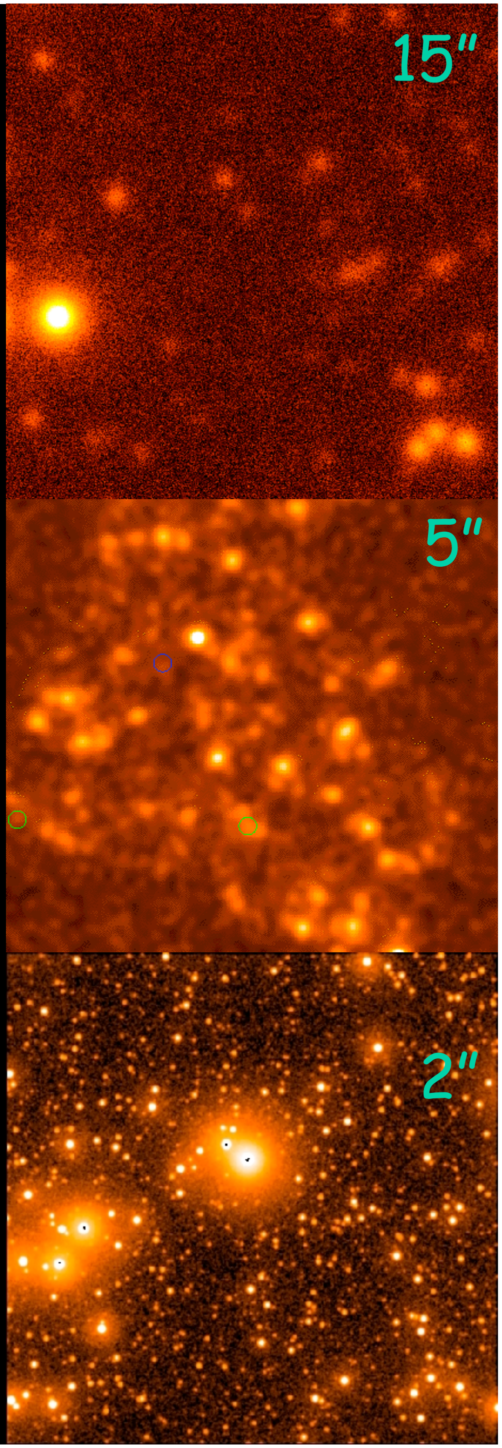
3. Mission Sensitivity Requirements



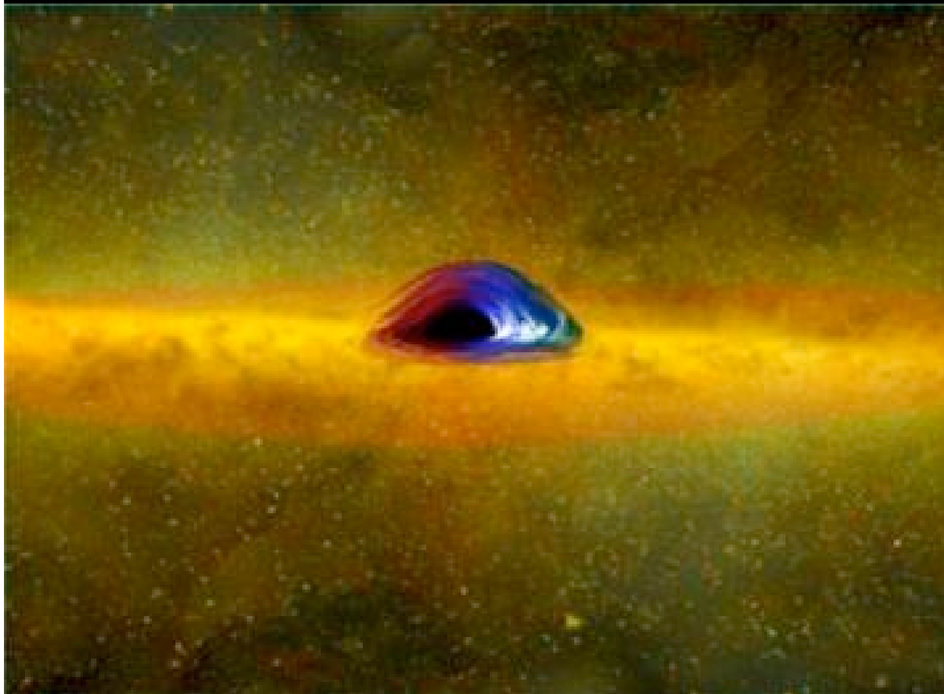

wfi_bp.grpl wfi_b.grpl stj_bp.grpl stj_b.grpl conx_bp.grpl conx_b.g
XEUS/Con-X
Backgrounds
XEUS
WFI 5'x5'
XEUS
NFI 1'x1'
Con-X TES
2.5'x2.5'
normalized counts/sec/keV
100
10
1
0.1
0.01
0.2
0.5
1
2
5
channel energy (keV)

Mission Sensitivity

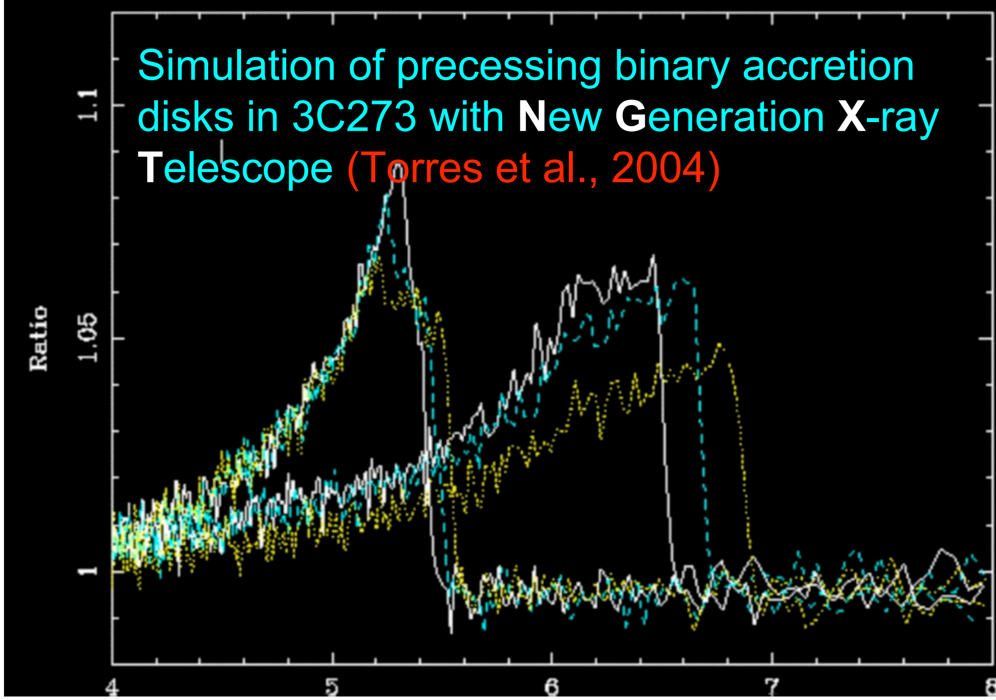


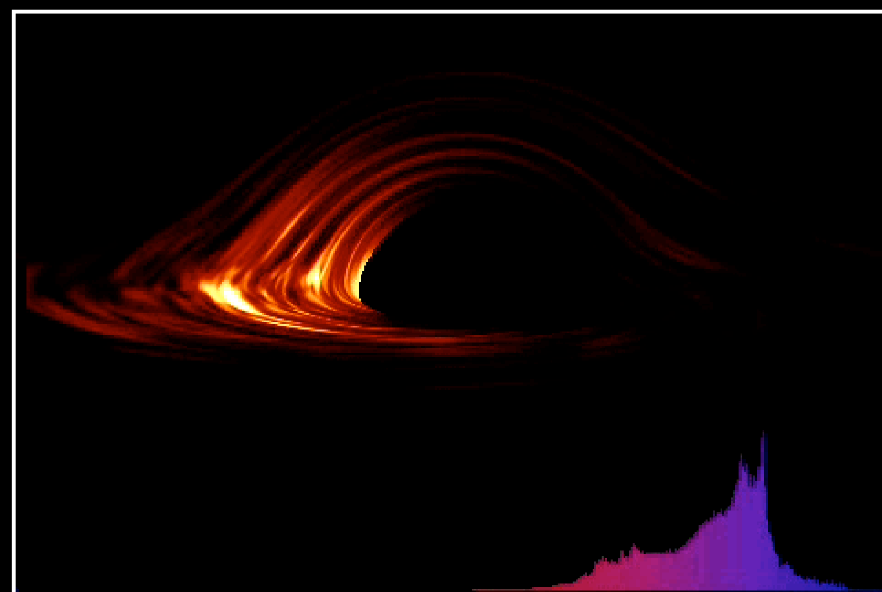


Approaching the Black Hole



Simulation courtesy Armitage & Reynolds

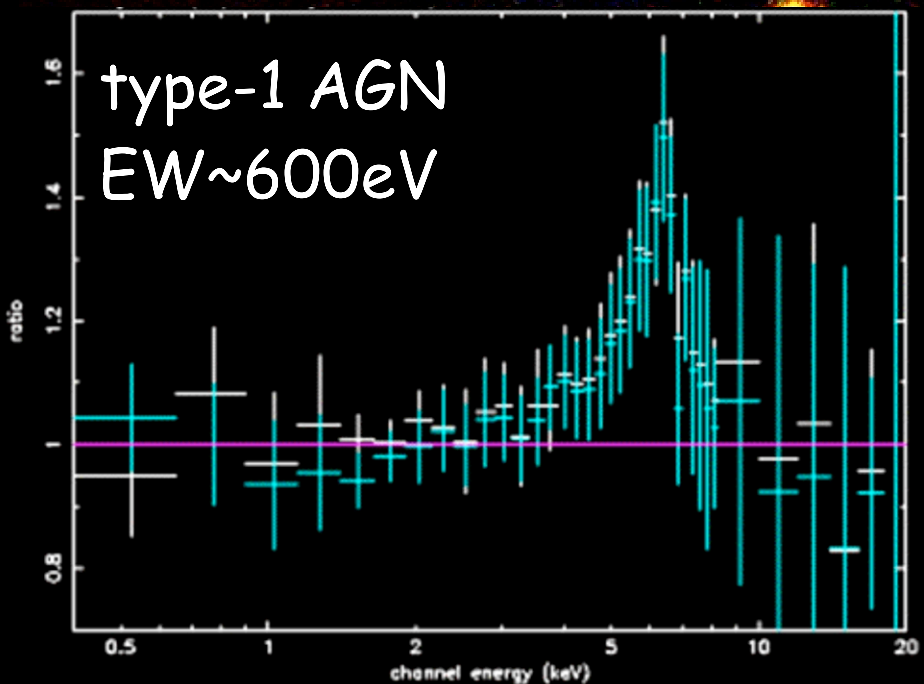


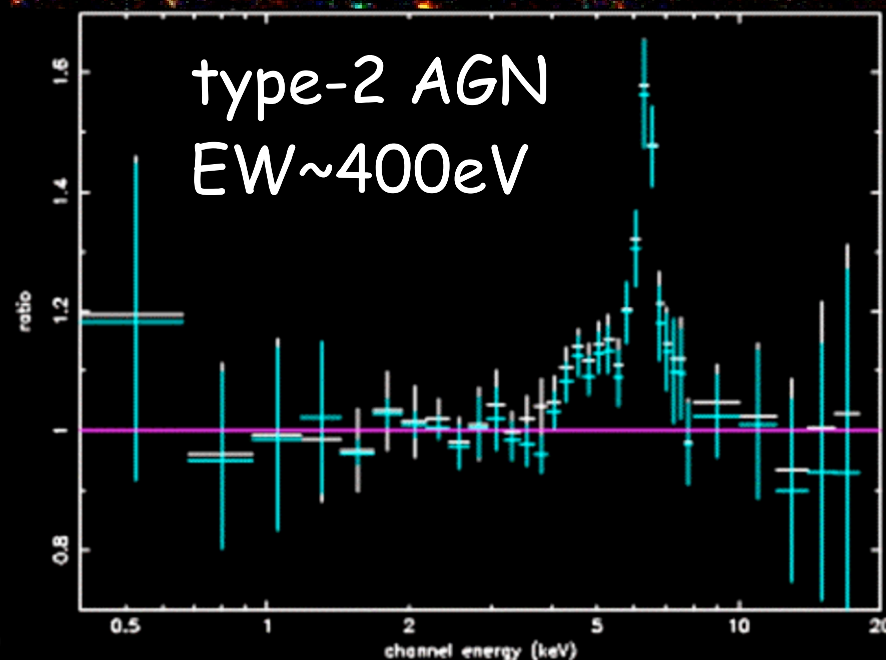


Lockman Hole

800 ks XMM-Newton observation

Average rest-frame spectra show relativistic Fe-lines



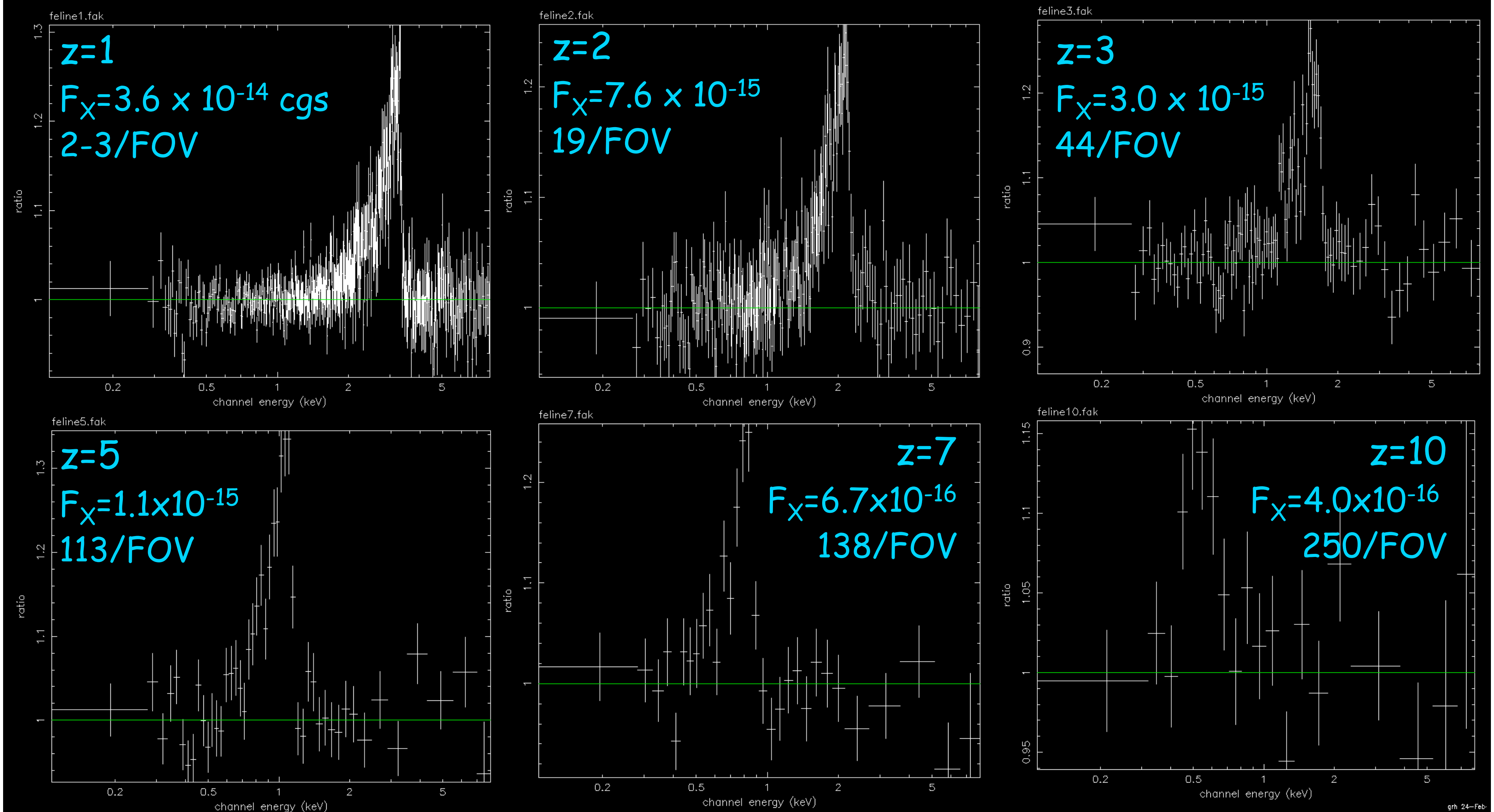


Streblyanskaya et al., 2004

New **G**eneration **X**-ray **T**elescope can determine redshifts and study Fe lines in each individual object

NGXT view of relativistic Fe line

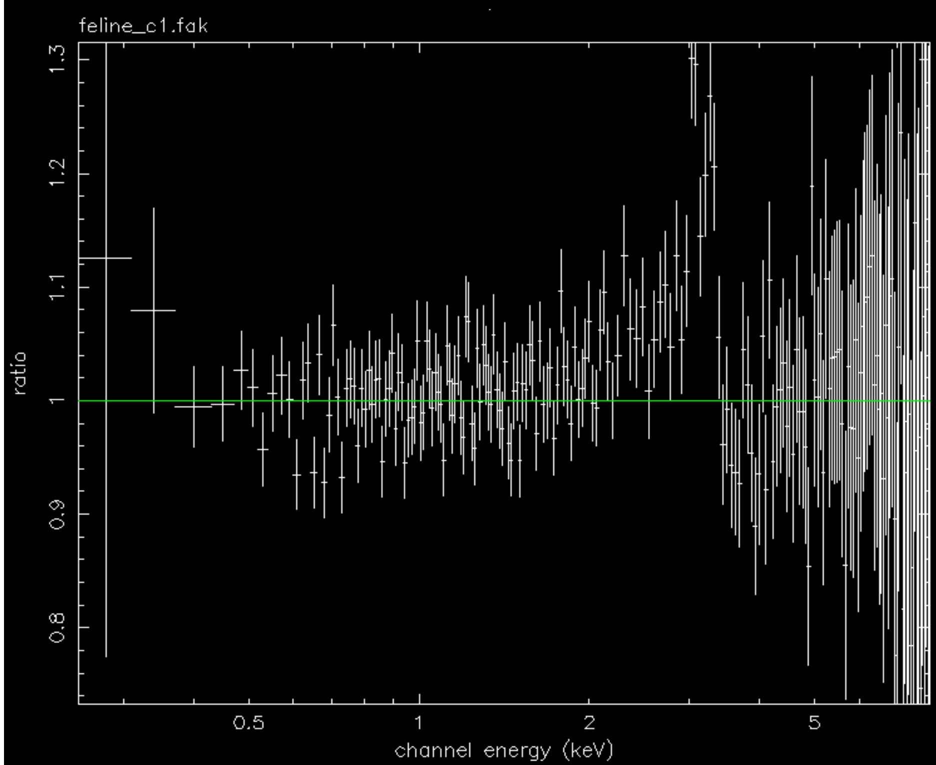
10^{44} erg/s QSO simulations



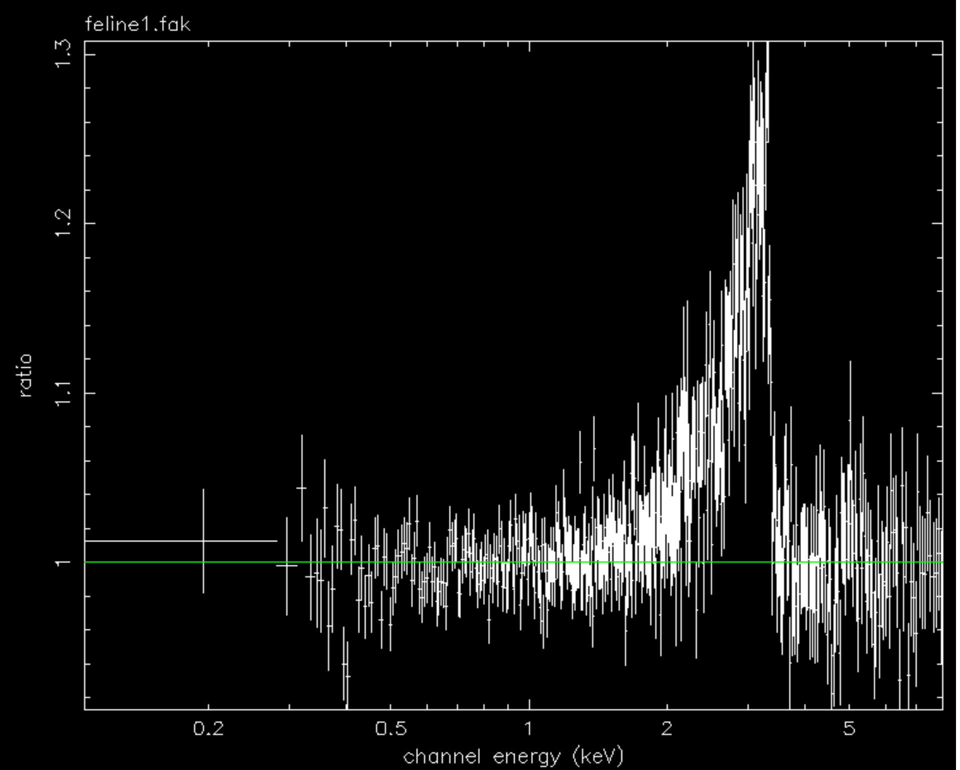
Number of objects is cumulative at that flux over all z!

Throughput Matters!

z=1 $L_X=10^{44}$ erg/s $F_X=3.6 \times 10^{14}$ cgs



1 Msec Con-X TES



1 Msec XEUS WFI

How to find these guys?

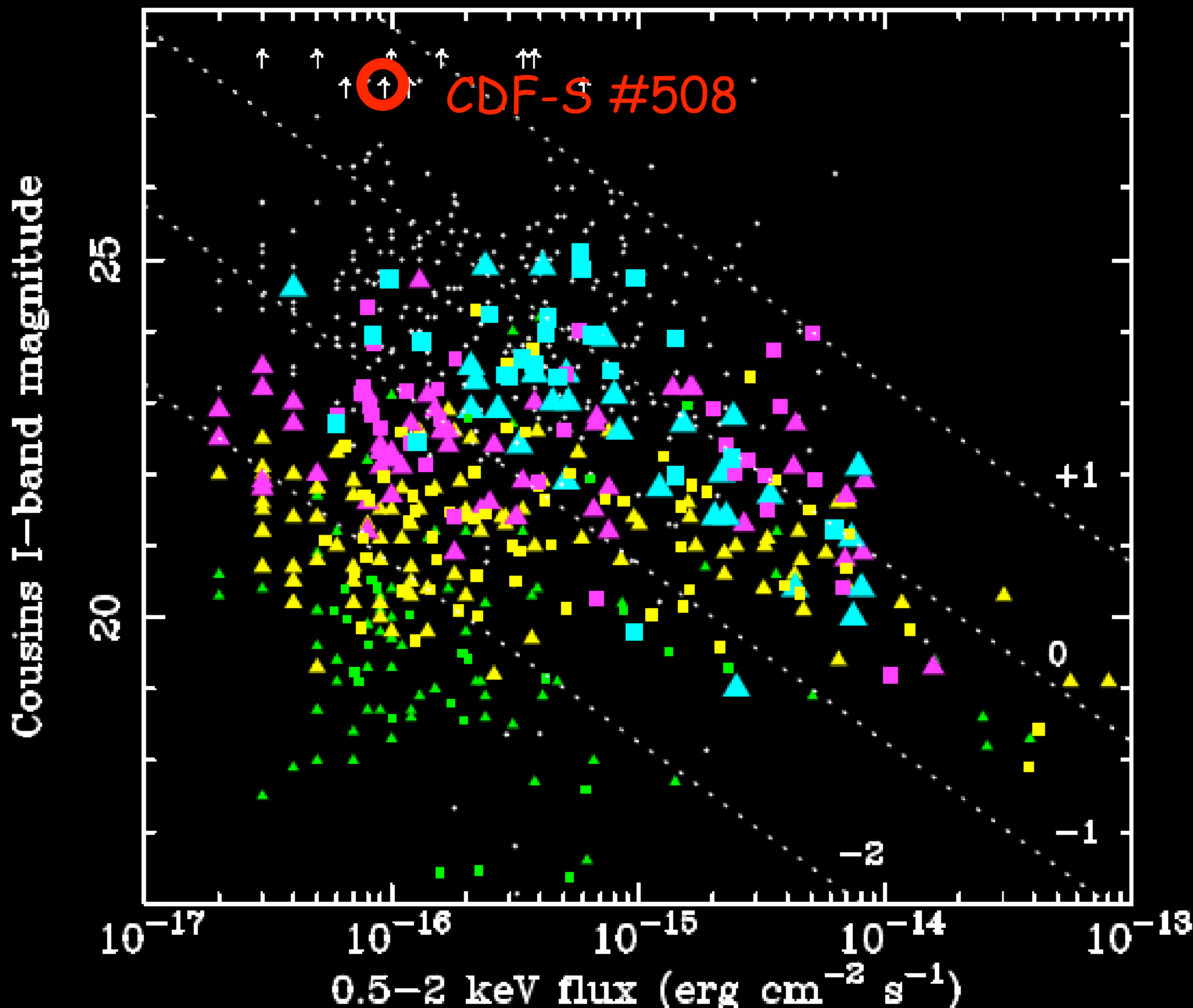
High-z QSO numbers assuming 3 NGXT Deep fields of 15 x 15 arcmin

zmin	zmax	constant	SSG
3	4	34	28
4	5	30	9
5	6	28	3
6	8	46	1.3
8	10	36	0.16

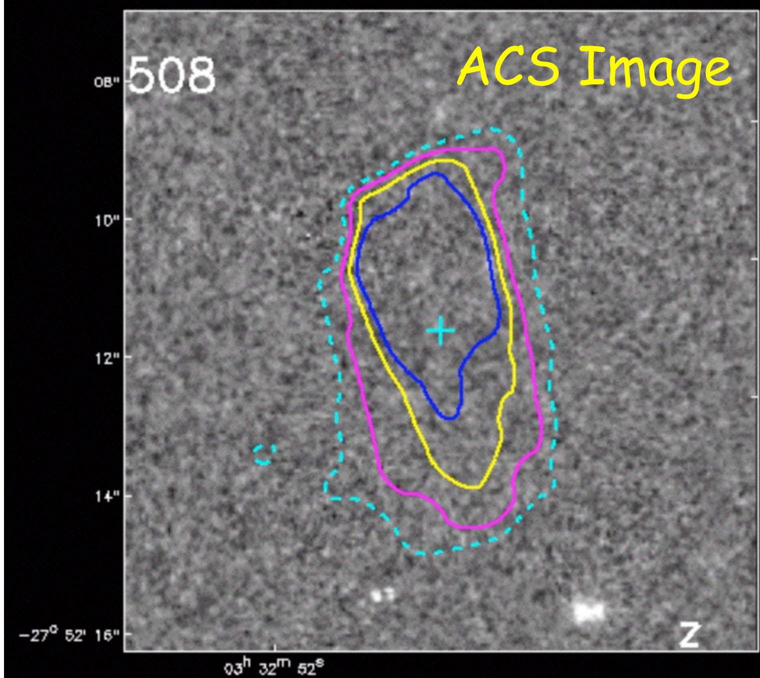
Tidal capture events + multiwavelength may help !

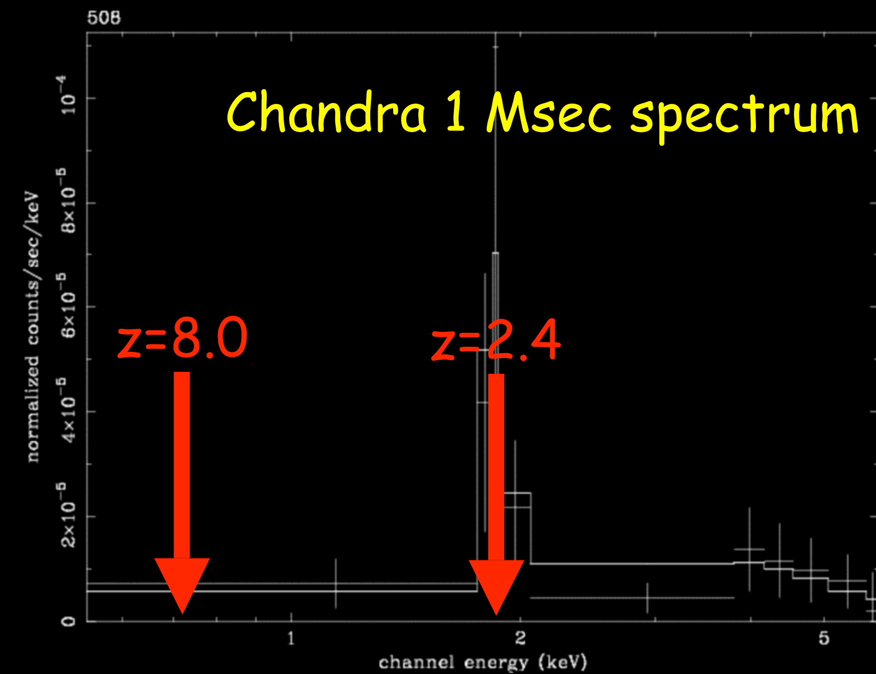
Extreme X-ray Optical Sources EXOs

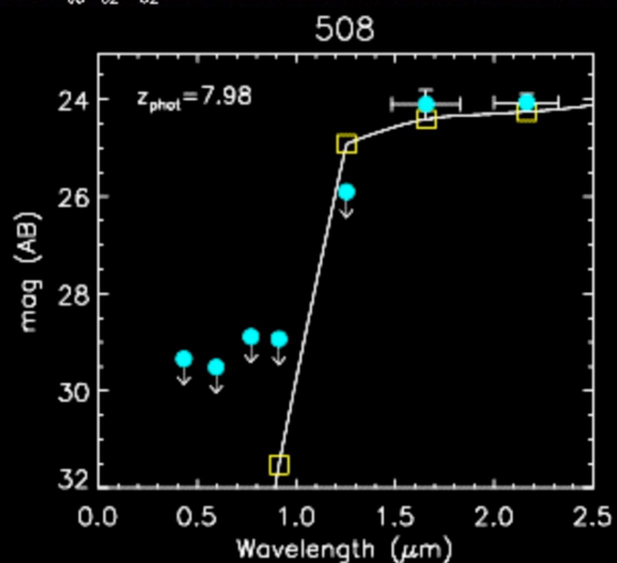
- Koekemoer et al., 2004 called them EXOs
- Most are visible in IR, but photo-z uncertain
- Clue is given by X-ray spectra in some cases
- Example CDF-S

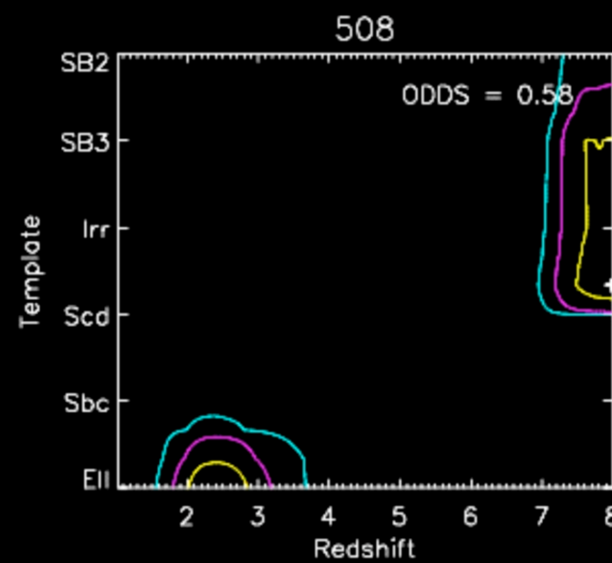


The EXO CDF-S #508









Mainieri et al.
GOODS photo-z

Summary

- Scientific Requirements
  - Sensitivity: 10^{-18} erg cm^{-2} s^{-1} _ > 10 m^2 area @1 keV
  - Energy Band 0.1 to ~100 keV
  - Angular resolution 2-5 arcsec
  - Spectral resolution 1-2 eV

NGXT science is exciting with strong interest across EU/US/Japan!

Science has highest priority in national planning excercises (e.g. NAS Decadal Survey, German „Denkschrift“) + ~100 scientist signatures

Coordinated planning in Europe, Japan and US

- Technology development required:
  - Factor ~ 10 lighter mirrors, high precision micropore optics
  - Formation flying, 1 mm^3 accuracy over ~50 m
  - Imaging calorimeter, better than 2 eV
  - Large, fast active pixel detector with _s timing

Proof of concept exists for key technologies!

Need sufficient technology investment NOW to be ready for


Thank you
very much!
esa
XEUS